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The General Secretary read the minutes of the previous meeting, which were confirmed and signed as a correct record.

The Chairman introduced the authors and the following paper was then presented in summary by Mr Manger.

APPLIED PETROLEUM RESEARCH ON A VEHICLE DYNAMOMETER*

By J. TUBMAN† and J. F. MANGER†

INTRODUCTION

THE petroleum industry supplies fuels and lubricants suitable for a variety of cars in use all over the world, and close co-operation is necessary between the automobile and petroleum industries to ensure the reliability and excellent performance which are characteristic of the modern car.

The car manufacturers have to design cars which meet the requirements of customers and which perform well in all the countries in which they are sold. These vehicles will perform satisfactorily under widely varying climatic conditions only if they are supplied with suitable fuels and lubricants. The petroleum industry must supply these materials; a task made more difficult by frequent changes in vehicle design, requiring different product specifications. There are three stages in the development of automotive fuels and lubricants:

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These difficulties can be overcome in two ways:

1. Provision of special proving grounds, such as the MIRA Proving Ground at Lindley. Ideally, this should be near the petroleum research laboratory.
2. Provision of dynamometers suitable for testing vehicles under simulated road conditions.

The second alternative is better for petroleum research because temperature and humidity can be controlled.

For these reasons The British Petroleum Co. Ltd installed a vehicle dynamometer at its Research Centre at Sunbury.

This installation has already been described in the *Automobile Engineer*[1] and only the main features are outlined in this paper.

DESCRIPTION OF DYNAMOMETER

The vehicle dynamometer, illustrated in Fig 1, was designed to test vehicles having power outputs from 28 to 300 bhp and fully-laden weights from 1700 to 4500 lb. Cooling air is blown over the car by a large centrifugal fan, the air speed increasing with the car speed. The test room air temperature can be controlled automatically up to 120° F (49° C), the minimum temperature being governed by that of the outside air. The air humidity can be varied within limits by manual control. The maximum test speed for continuous operation is 100 mph.

Two Heenan and Froude Mk I eddy-current dynamometers simulate hill-climbing conditions and vehicle weight in excess of the weight due to inertia of the plant, which is 1700 lb. The effect of the additional inertia is obtained by electronic control of the dynamometer field current to provide a torque proportional to the rate of acceleration of the system. By introducing the appropriate constant torque, gradients can be simulated. These conditions can be applied together or separately.

An electric tachometer driven from the hub of one of the steel rolls generates a voltage directly proportional to the car speed, and this voltage is differentiated electronically to give a signal proportional to acceleration. The acceleration signal is multiplied by a factor corresponding to the weight of the test vehicle as set on the controls. Strain gauges mounted on a linkage attached to each eddy-current dynamometer give a signal proportional to the torque applied to the dynamometers. The strain gauge signal and the

* MS received 28 July 1960.

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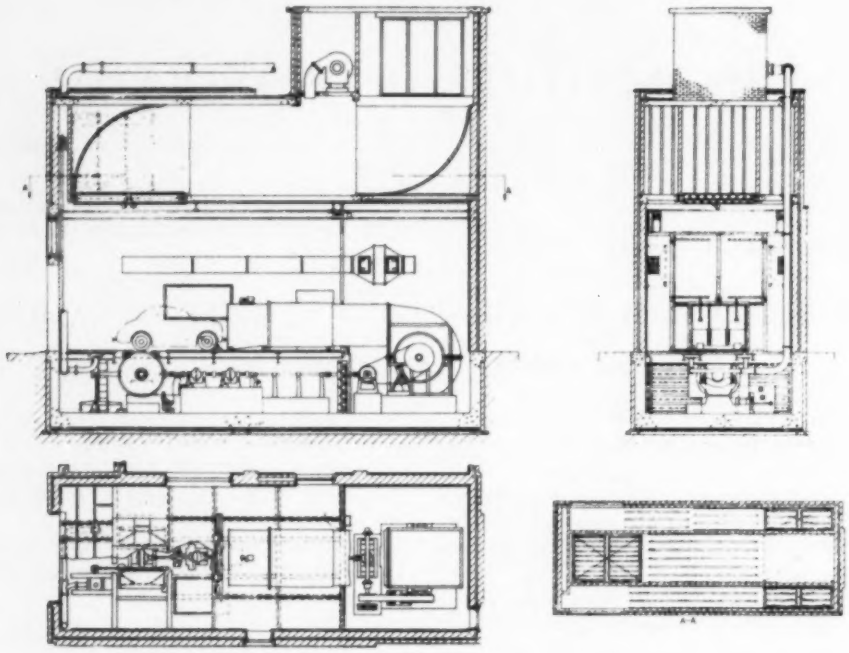

FIG 1

GENERAL ARRANGEMENT OF THE DYNAMOMETER INSTALLATION AT THE SUNBURY RESEARCH CENTRE

acceleration signal are compared algebraically, and the resultant voltage controls the dynamometer field current, and hence the applied torque.

The vehicle can also be held at constant speed at any throttle opening greater than that normally required at that speed by using a constant speed circuit.

INSTRUMENTATION

In the control panel shown in Fig 2 are the instruments which indicate the operating conditions of the vehicle on test and of the dynamometer components. There are two automatic recorders, one of which indicates various car component temperatures and the other plant component temperatures. Gauges show engine speed, car speed, ignition spark advance, and the speed of the air flow over the car. A manometer provides information from which the rear wheel torque may be calculated. Switches for the various pumps, motors, and heaters are grouped to the left of the controls for the test cell air temperature and humidity, and two levers enable the test car throttle position and engine spark advance to be adjusted. The electronic equipment for simulating car inertia and gradient is grouped in one of the desk pedestals, the controls on the panel being duplicated in the test vehicle. Both test and total vehicle dynamometer mileage are recorded. A two-way communication set is provided for use when a vehicle is occupied by test personnel. An electronic timer mounted above the panel automatically checks car acceleration times over any speed range.

Safety devices, to protect the operating staff and machinery, switch off the vehicle ignition circuit when a major fault develops. This stops the plant, since

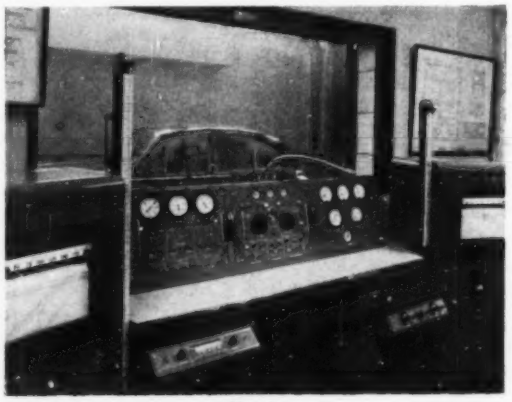

FIG 2

VEHICLE DYNAMOMETER CONTROL PANEL

the test car is the only source of motive power. One other important safety device is a continuous sampling carbon monoxide alarm situated in the test cell to give adequate warning should the carbon monoxide concentration reach 0·01 per cent.

Noise is particularly important when rating fuels or determining vehicle octane requirements, and the noise level inside a car on the dynamometer must be similar to that experienced on the road. Also the noise outside the vehicle dynamometer building must be reduced to an absolute minimum, otherwise annoyance may be caused to occupants of other laboratories or private dwelling houses in the vicinity; our vehicle dynamometer was therefore insulated acoustically to meet these requirements.

ADVANTAGES OF A VEHICLE DYNAMOMETER

The Sunbury Research Centre vehicle dynamometer was designed in the first instance so that octane requirements and fuel ratings could be made under the conditions laid down in the accepted procedures.

Tests of this type require level road accelerations to high speed, and these facilities were therefore provided. Independence of weather conditions allows us to carry out the large number of fuel anti-knock ratings and octane requirement determinations called for by our research programmes. The needs of such programmes could not be fulfilled by road tests, with their attendant delays caused by bad weather and heavy traffic. A further advantage is that the auxiliary Research Centre facilities for maintenance, servicing, analysis, etc., are available on the spot. By controlling atmospheric conditions the accuracy of octane number requirements and fuel ratings is improved, and the amount of work necessary for a given evaluation reduced. The vehicle dynamometer is also used to determine the volatility tolerance of a car and for engine temperature surveys, work for which ambient air temperature control is an advantage.

Although used mainly for gasoline rating, the dynamometer is also used for lubricating oil work, particularly when a lubricant has to be tested in an engine not normally installed on one of the test benches. In a case like this it is convenient to be able to do the test in a complete car on the dynamometer.

When assessing the effect on engine performance of compression ratio changes or other modifications, it is an advantage to be able to measure engine performance in road trim. Again, the ignition requirements of a modified engine are preferably determined with the unit installed in a vehicle. In both instances the dynamometer is the ideal tool.

Further work for which the vehicle dynamometer was not designed, but for which it proved very useful, was testing the engine cooling system of a Grand Prix racing car. In a series of tests it was possible to compare the efficiencies of different oil and water cooling system layouts in which cooler designs, materials, mounting positions, and air ducting were varied.

Finally, new staff can be taught the various road testing techniques more easily on the vehicle dynamometer, since equipment, fuel, and expert tuition are readily available.

CORRELATION

Correlation between road and vehicle dynamometer results is checked periodically to ensure that engine and vehicle design changes do not upset the reliability of data obtained on the vehicle dynamometer.

PERFORMANCE

The results of acceleration tests made on three cars are illustrated in Fig 3. This shows the ability of the vehicle dynamometer to reproduce the level road acceleration performance of vehicles.

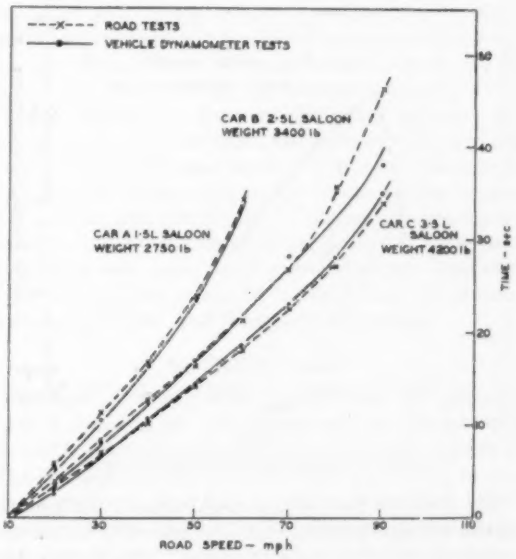

FIG 3

COMPARISON BETWEEN ACCELERATION TIMES AT WIDE-OPEN THROTTLE IN TOP GEAR ON THE ROAD AND ON THE VEHICLE DYNAMOMETER

ENGINE OCTANE REQUIREMENT

Engine octane requirements are of importance to both the petroleum industry and the motor manufacturer. An octane requirement, determined with primary reference fuels, is the percentage of *iso*-octane in the blend of *iso*-octane with *n*-heptane which just gives knock-free operation in that particular engine.

The method employed to obtain octane requirements is common to both road and vehicle dynamometers. The car is run on a primary reference fuel and accelerated in top gear with wide-open throttle from the lowest practicable speed for the car in question, usually 1000 rev/min to 3500 engine rev/min. Full throttle knock-in and knock die-out speeds are noted.

Combustion chamber deposits influence engine octane requirements and, to disturb the combustion chamber deposits as little as possible, knock must be kept at trace level. This is done by gradually closing the throttle as the knock becomes heavier than trace, but ensuring that wide-open throttle has been reached again just prior to knock die-out. The procedure is repeated using primary reference fuels of decreasing anti-knock value until sufficient date have been obtained to plot curves as shown in Fig 4, from which the octane requirement can be seen to be 93 ON.

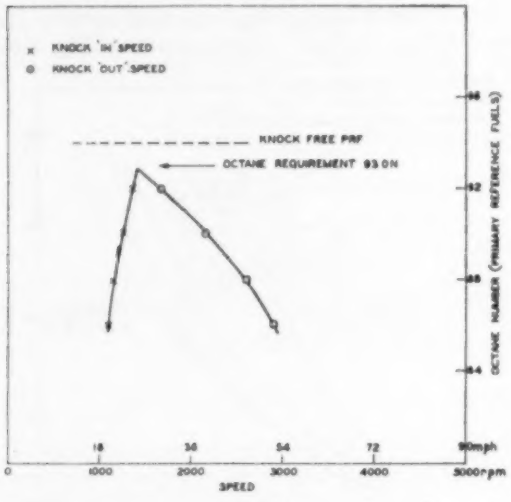

Fig 4

OCTANE REQUIREMENT DETERMINATION

Fig 5 shows that octane requirements determined on the vehicle dynamometer were generally within one octane number of the road value. This despite the fact that in these 40 observations, 11 cars were used and 13 observers were involved. The repeatability of octane requirements obtained on the road is in general no closer than one octane number.

FUEL RATING

The Modified Uniontown procedure is generally considered to be the best indication of a motorist's evaluation of the anti-knock quality of a gasoline. The instrumentation necessary for this procedure is simply a control within the car for adjusting the basic ignition timing, and a reliable means of measuring this timing together with the engine or vehicle speed. Gasolines are rated during wide-open throttle top gear accelerations from the lowest practicable speed to 3500 engine rev/min. During the accelerations, the ignition setting is adjusted to give trace knock at the speed of maximum knock for each of a series of primary reference fuels, trace knock being defined as the first audible knock which can readily be reproduced. A curve of critical ignition timing for trace knock

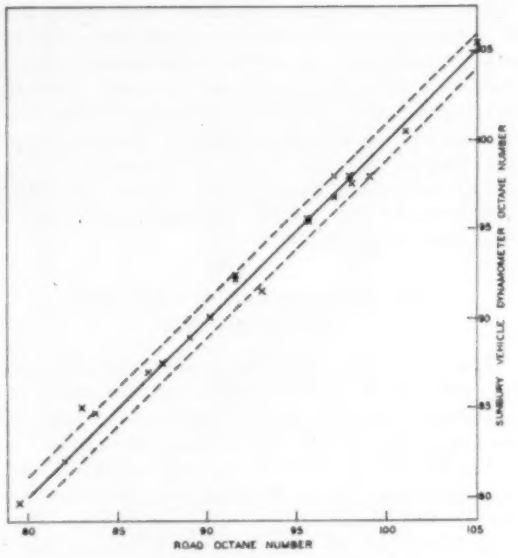

Fig 5

ENGINE OCTANE REQUIREMENTS OF 11 CARS—ROAD/VEHICLE DYNAMOMETER CORRELATION

against reference fuel octane number is then developed, as shown in Fig 6. Using this curve, the road anti-knock rating of any gasoline may then be obtained by the same procedure. From Fig 6 it can be seen that fuel A, which required a static ignition timing of $12\frac{1}{2}°$ before tdc to produce trace knock,

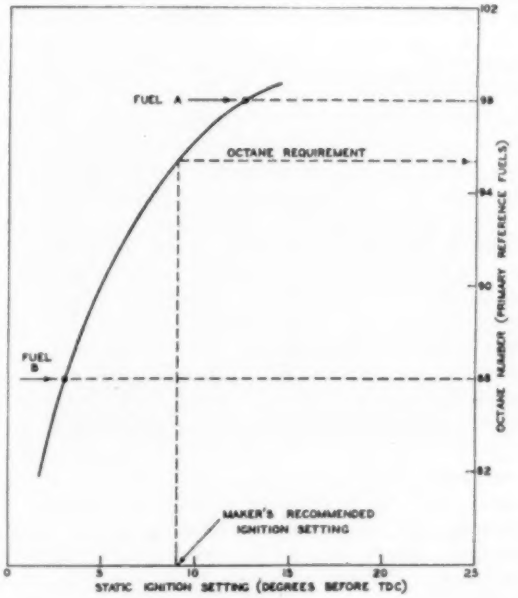

Fig 6

TYPICAL MODIFIED UNIONTOWN FUEL RATING CURVE

would be given a rating of about 98 ON; while fuel B, requiring a trace knock spark advance of 3° before tdc, would have a rating of 86 ON.

This procedure applies without modification whether the tests are conducted on the road or on the vehicle dynamometer. The correlation between fuel

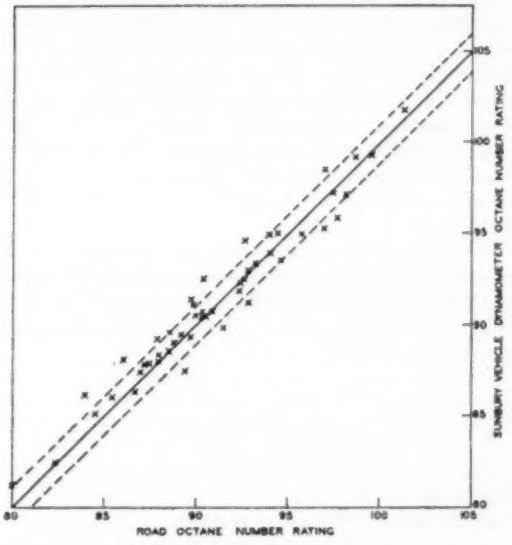

FIG 7

MODIFIED UNIONTOWN RATING OF 12 FUELS—ROAD/VEHICLE DYNAMOMETER CORRELATION

ratings is shown in Fig 7 and indicates that 75 per cent of the road and vehicle dynamometer ratings differed by less than one octane number. The maximum difference for any one fuel was two octane numbers. These observations were part of a normal test programme which involved seven cars, ten observers, and 12 test fuels.

ENGINE AND FUEL SYSTEM TEMPERATURES

These temperatures are measured to provide information about the conditions under which fuels and lubricants operate in a car on the road. This information often shows that there are wide variations between the temperatures of components of cars of different design. The data obtained also enable actual operating conditions to be simulated when working with engines installed on the test bench. Temperatures measured by thermo-couples inserted in the engine components are indicated on a meter carried in the car or registered on a recorder on the vehicle dynamometer control panel.

The correlation between temperatures obtained on the road and on the vehicle dynamometer is satisfactory at all speeds. Results of temperature survey made on four cars are given in Table I. It should be noted that the road and vehicle dynamometer work cannot always be done at the same ambient air temperature, and therefore the authors have applied their established correction of 1° C per 1° C change in ambient air temperature to the results on the engine fuel system, and 2/3° C per 1° C change in ambient air temperature for the oil-filled components. These correction factors have been established by extensive tests on a variety of cars in North Africa in summer, Sweden in winter, and Europe in all seasons.

VAPOUR LOCK

Normally, vapour lock occurs when the gasoline vapour forms in the fuel system and so restricts the flow of fuel to the engine that its operation is impaired. The limiting restriction to fuel flow may occur in the fuel pump, the fuel line, or the carburettor. Frequently, vapour lock results in complete engine failure, and once failure occurs fuel pump and line temperatures must be considerably reduced before the engine can be restarted.

TABLE I

Engine and Fuel System Temperatures Road/Vehicle Dynamometer Correlation

Vehicle	Ambient air temp, °C	Speed, mph	Engine and fuel system temperatures, °C													
			Under bonnet air		Petrol pump inlet		Petrol pump outlet		Carburettor bowl		Air intake		Water in head		Sump oil	
			Dynamo-meter	Road	Dynamo-meter	Road	Dynamo-meter	Road	Dynamo-meter	Road	Dynamo-meter	Road	Dynamo-meter	Road	Dynamo-meter	Road
A	25·6	30	40·5	37·5	39·5	36·5	40·0	37·5	41·5	40·5	44·0	44·5	80·5	85·0	81·0	86·0
		60	41·5	38·5	40·0	38·5	40·5	40·5	43·0	41·5	45·5	45·5	85·0	84·0	105·0	104·0
		80	41·5	42·5	42·5	42·5	41·5	42·5	43·0	45·5	45·0	49·5	89·0	91·0	121·0	127·0
B	26·7	30	44·0	39·5	43·0	41·5	45·0	42·5	41·0	38·0	50·0	44·5	77·0	77·0	81·5	81·0
		45	40·5	42·0	39·5	43·0	40·0	43·5	37·0	38·0	46·0	46·5	75·0	80·0	91·5	96·5
		65	42·0	36·5	37·0	38·5	38·5	39·5	36·5	36·0	46·0	45·5	82·0	79·0	100·0	98·0
C	25·6	30	44·0	42·0	35·0	38·0	35·5	43·0	42·5	40·0	47·0	42·0	80·0	79·0	95·0	86·0
		60	49·0	57·5	36·0	35·0	38·0	41·0	45·0	42·0	45·0	36·5	81·0	79·0	120·0	116·0
		80	50·0	44·0	39·0	41·0	42·0	42·0	49·0	49·0	44·0	42·0	92·0	85·0	128·0	130·0
			Under bonnet air		Cylinder barrel 2		Cylinder head 2		Cylinder barrel 3		Cylinder head 3		Air intake		Sump oil	
D	26·7	30	47·0	44·0	103·5	105·0	129·5	129·0	115·5	112·0	126·5	122·0	31·0	31·0	83·0	78·0
		50	49·0	48·0	116·5	119·0	137·0	138·0	120·5	122·0	136·5	137·0	32·0	35·0	93·0	91·0
		65	55·0	55·5	131·0	128·5	149·0	150·5	135·0	130·5	158·5	149·5	36·5	40·5	117·0	102·5

Vapour lock is most likely to become evident when attempting to restart the engine or when accelerating after being stopped for a short period, particularly when the previous driving was at sustained high speed or included hill climbing. The vapour lock symptoms may be uneven acceleration, continuing for perhaps a mile or more until the fuel system has cleared itself of vapour or, in more severe cases, complete loss of power or inability to start. Some vehicles are more prone to vapour lock than others, either because the critical parts run hotter or because the ratio of vapour to liquid fuel which the fuel system can handle and still give trouble-free operation is less. Atmospheric temperature directly influences the temperature of all engine components and, because the amount of vapour formed by a gasoline depends on its temperature, pressure, and volatility, it is important that engines and fuels should be designed to operate satisfactorily at the highest atmospheric temperature that prevails for several hours on the hottest day in the year in the particular country to which they are supplied.

When testing a car for vapour lock it is driven at about 80 per cent of its maximum speed until all component temperatures are stable, the engine is then switched to the test gasoline, and the car continues at the same speed until the temperatures stabilize again. The car is then stopped in a sheltered position for 15 minutes, during which time the fuel system temperatures rise. After this the vehicle is restarted and idled for 5 seconds before driving away at wide-open throttle, top gear being engaged as soon as possible. As previously explained, vapour lock is indicated by failure to start or by misfiring and uneven running during acceleration.

TABLE II

Vapour Lock Tolerance Road/Vehicle Dynamometer Correlation

Vehicle	Fuel pump type and location	Test location road or vehicle dynamometer	Critical ambient air temperature when using a typical "summer" season premium quality gasoline	
			Incipient vapour lock, °C	Full vapour lock, °C
A	Mechanical, offside opposite to exhaust	Road	31·1	34·6
		Dynamometer	31·7	37·3
B	Mechanical, nearside opposite to exhaust	Road	40·3	47·4
		Dynamometer	40·3	49·8
C	Mechanical, offside opposite to exhaust	Road	25·9	30·4
		Dynamometer	27·3	32·2
D	Mechanical, at centre rear of engine	Road	38·7	43·5
		Dynamometer	39·4	44·4

The vehicle dynamometer has been found to be extremely useful for this work, as it permits close control of test conditions and allows us to test at constant ambient air temperature regardless of the outside air temperature. For vapour lock tests the vehicle dynamometer fan load and plant inertia are set to reproduce level road conditions for steady speed running and wide-open throttle acceleration, applicable to the vehicle on test. The test car is driven in the same manner as for vapour lock tests on the road—in fact, the whole test procedure is identical for road or vehicle dynamometer.

The data in Table II show that there were no significant differences between the vapour locking tolerances obtained for each car on the road and on the vehicle dynamometer. The vapour tolerance has been expressed as the critical ambient air temperatures at which incipient and complete vapour lock will occur in each vehicle when using a typical British summer season gasoline designed to give satisfactory operation up to an ambient air temperature of at least 30° C (86° F).

It is believed that the repeatability obtained on the road during vapour locking tests, in terms of critical ambient air temperature, is of the order of 2° to 3° C; hence the road and vehicle dynamometer correlation shown is favourable.

CONCLUSIONS

The data obtained from vehicles on the vehicle dynamometer are representative of data obtained from the same vehicles on the road.

A vehicle dynamometer offers many advantages for fuel, lubricant, and engine testing in vehicles under simulated road conditions. These are as follows:

1. Test programmes completed in less time. Useful test miles are obtainable every day of the year with no delays due to bad weather or traffic interference and non-productive mileage is reduced. Testing is easier and quicker because the vehicle itself is stationary.
2. Standardized test conditions improve the reproducibility of data by eliminating weather variables and allow direct comparisons to be made between tests conducted over long intervals.
3. Controlled air temperatures ranging from ambient up to 120° F (49° C) are readily available. This avoids the almost inevitable delay of waiting for the desired weather conditions and reduces the amount of overseas testing required.
4. Complicated and bulky instruments and equipment not readily adaptable for use on the road can surround the test vehicle.
5. Vehicles and instruments can be readily serviced by staff available on the site.
6. Ability to test at high speed. Vehicle crews can concentrate solely on the test work, being relieved of the distractions and nervous stresses involved in fast driving on the public highway.
7. Our dynamometer has been used for more than 150,000 miles of test work, and it is believed

that the results from this work have been obtained more economically than if the tests had been made on a special road circuit or on the public highway.

Finally, a vehicle dynamometer can be an even more useful piece of equipment if it is made to provide low temperature test conditions. This would allow other aspects of fuel and lubricating oil performance to be investigated, the more important of these, not mentioned in this paper, being cold starting and warm-up. These cooling facilities would also be used to reduce the test room temperature to give the required standard test temperature on hot summer days.

ACKNOWLEDGMENTS

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DISCUSSION

P. V. Lamarque (Associated Ethyl Co. Ltd): The vehicle dynamometer is a more widely used piece of equipment in the U.S.A. than in the U.K., and for this reason the authors are to be congratulated on the very clear description they have given of their particular piece of equipment. It would be invidious to make any comment on the detailed design, which in most cases is conditioned by questions of space, cost, and the range of work which is envisaged. One notices the use of eddy-current dynamometers for power absorption, which provide extreme flexibility of control, and the possibility of programme control by the use of magnetic tapes, as is now practised in the U.S.A.

However, it should be made clear that the vehicle dynamometer has certain limitations. It will not, for instance, provide any information about the general road behaviour of the vehicle, its suspension, steering, etc; and in the form in which it has been developed by various laboratories attached to the petroleum industry, its use is limited mainly to investigating the general relationship between the engine and its fuel and lubricant. It can also be used to provide information on the losses which occur between the engine flywheel and the driving wheels of the vehicle. I think these limitations should be understood, so that too much is not expected from testing equipment of this kind.

I would agree entirely with the conclusions given by the authors, but I feel that they should be qualified in that some of the results obtained on the dynamometer must be referred back to the road. In our view, the vehicle dynamometer is an adjunct to road testing, and does not entirely replace the need for some work on the road. Particularly is this true of work in connexion with the octane requirement of vehicles, where our experience suggests that the acceleration characteristics of the vehicle must be determined on the road to establish critical knock speed ranges with sufficient accuracy. This is certainly so with cars having low speed knocking characteristics, where the critical knock speed is not far removed from the lowest non-snatch speed in top gear on the road. Starting the acceleration below the lowest non-snatch speed gives an unrealistic value of the road octane requirement of the vehicle.

Our experience has also shown that the vehicle dynamometer does not completely represent road conditions, particularly as regards air flow round the vehicle, where the absence of relative movement with the road affects quite considerably the cooling of under-body parts, and also the extraction or movement of air from underneath the bonnet. I think corrections could be made for some of these factors, but they do in fact represent important departures from strictly road conditions.

The authors mention the use of the vehicle dynamometer in assessing the effect of modifications to engine performance. I do not know how much work the authors have done in this field, but one of the difficulties lies in the measurement of the losses which occur between the engine flywheel and the driving wheels of the vehicle. These losses are susceptible to changes with load and speed, which in themselves may mask small changes in engine performance. The authors' comments on the application of correction factors to the power available at the driving wheels for changes in ambient conditions would be welcome.

I am very interested to learn of the work that has been undertaken on the dynamometer in connexion with engine cooling systems. I would be particularly interested to know whether the authors were able to make absolute comparisons, or merely relative ones, in view of the differences already mentioned, in the air flow conditions between the dynamometer and the road.

With regard to the results of engine octane requirements which the authors have obtained, our experience is that the requirements on the dynamometer tend to be higher than on the road, particularly in cars suffering from high wind noise. But by and large we would agree with the correlation which the authors have obtained between road and dynamometer.

I would also welcome further explanation of Figs 5 and 7, whether the points on those figures represent the result of one test, or are in fact the average of several tests. In any event, I think they show a remarkable correlation between the dynamometer and the road.

We have found, on our own dynamometer, that with a coupled cooling fan the matching of engine and transmission temperatures with those obtained on the road is not as easy as may be suggested by the authors. The provision of a cooling blast of the same velocity as that of the vehicle on the road does not give quite the same temperatures under all simulated conditions, due to the absence, as already mentioned, of relative movement between the vehicle and the road, which affects air flow over the under-body parts.

I was particularly interested in the engine and fuel system temperatures given in Table I. My impression is that the sump oil temperatures are rather higher than in most of the cars we have tested. However, the real problem resides in controlling these temperatures during prolonged running on the dynamometer at high speeds and full throttle. We would say that it is possible to

correlate road and dynamometer temperatures at relatively low loads and speeds, but as both of these parameters increase it becomes more difficult to prevent temperatures from rising above road conditions.

I have no comments to offer about vapour lock, as so far we have not undertaken any work on this subject.

Finally, and completely as an aside, I would be most interested to learn of the authors' experience with front-wheel drive vehicles on their particular dynamometer.

J. Tubman: We agree that a vehicle dynamometer has certain limitations for vehicle test work, and that its primary value lies in its application to the petroleum industry. If we have given the impression that we can now throw away road tests, this was not intended. There must always be a minimum amount of road testing to ensure keeping abreast of vehicle design trends which may affect the reliability of data obtained on the vehicle dynamometer. We agree, too, that vehicle acceleration obtained on the road must always be matched on the dynamometer before doing octane requirement work or fuel ratings. I endorse Mr Lamarque's remarks that accelerations started at too low a road speed on octane requirement or fuel rating determinations can definitely affect the results.

Our plant was primarily designed for petroleum testing. However, we have done a certain amount of engine performance work, and we can detect small differences in power output during vehicle performance testing. We have found that the most important point with regard to comparisons on engine performance is that the work must be done on the same engine in the same vehicle.

We do use some correction factors in all our work, both on the test beds and the vehicle dynamometer. The correction factor (CF) used is

$$CF = \frac{29{\cdot}92}{\text{abs atm pressure}} \times \sqrt{\frac{273 + t}{288}},$$

where t is test cell ambient air temperature, ° C.

We use this correction only on the vehicle dynamometer, however, when doing wide open throttle performance work.

With regard to the question on whether relative comparisons were made on the Grand Prix racing car mentioned in the paper, yes, they were relative.

Mr Lamarque mentioned the octane requirement and fuel rating correlations and wished to know whether they were the results of more than one rating. Yes, the correlation was obtained from duplicate road and dynamometer ratings.

With regard to cooling the car on the plant, we agree that care has to be taken in this, particularly to ensure that the transmission temperatures do not get to levels appreciably higher than the road values, a condition that one faces especially when working for prolonged periods at wide open throttle. We would advocate that provision should always be made for a certain amount of additional cooling air under the vehicle for this type of work on a vehicle dynamometer.

I am not too happy that Mr Lamarque found the sump temperatures quoted in Table I rather higher than he has been used to, because those we have shown are stabilized sump oil temperatures at steady speeds during test work and are, in our experience, typical during summer ambient air temperatures. These temperatures were measured by a thermo-couple in place of and at the same depth as the sump oil dipstick.

We have not had a great deal of experience with front wheel drive vehicles on the vehicle dynamometer. We can accommodate small front wheel drive cars, but find that they are inherently unstable on the over-run. Chocking the rear wheels only is insufficient, and it is found necessary to restrict the sideways movement of the front of the vehicle.

Dr G. Moss (Esso Research Ltd) (read in his absence by K. Arter): It is not to be doubted that a vehicle dynamometer is a very useful piece of equipment to have. It is encouraging to learn that road conditions can be reproduced so closely on the Sunbury dynamometer, and the authors' conclusions regarding the advantages of the equipment are irrefutable. Indeed, the only unfortunate feature of the dynamometer *per se* is that this elaborate, highly expensive piece of equipment is able to deal with only one car at a time.

The authors are to be congratulated for the precision and clarity with which they have set out the merits of the vehicle dynamometer. There is, however, one point

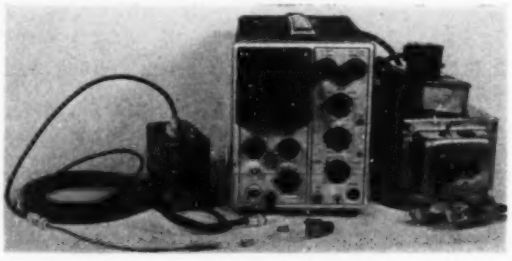

FIG A

which is rather puzzling. This is that whilst one of the many advantages is that one can surround the test car with as many instruments as are required, it is evidently still the practice at Sunbury to use the operator's ears as knock detectors. We at Abingdon have been using some most effective electronic knock-detecting equipment for a considerable time, on the road as well as on the test bench. We find this equipment especially valuable in high-speed knock studies, in conditions under which audible knock can result in serious damage to the engine. It also has the virtue of allowing cylinders to be rated individually.

For a detecting element we use the spark plug mounted PZ 6 quartz crystal pick-up, supplied by Vibramat AG. A modified spark pick-up and screened lead are shown in the foreground of Fig A. The output from the pressure detector is fed to a Model S-31 Serviee Scope oscilloscope, made by Telequipment Ltd. This is fitted with a tied base trigger circuit, which operates only when the input exceeds a set value and is of the correct positive or negative rate. By this means the display is restricted to the relevant part of the combustion cycle, and is held on the screen irrespective of changes in engine speed. The box at the left is a switch unit, which enables the desired cylinder to be selected, whilst the battery-operated power pack is shown on the right. The oscilloscope is small and light enough to be held on the knees without any discomfort.

The type of signal which is displayed depends on the electrical impedance of the detection system, which consists basically of a capacity and resistance in series. If the resistance is sufficiently high, then the signal displayed, which is effectively the voltage across the resistance, will represent a pressure/time relationship. If the resistance is reduced to a low value, then the display will represent the rate of change of pressure in respect to time. This has the advantage of making knock signals stand out more clearly because of the high frequency.

In fact, it has been found that the best results are obtained using a display which is partly pressure, and partly rate of change of pressure. Examples of the signals are shown here (Fig. B) and I think the illustration is self-explanatory. The difference between the top picture and

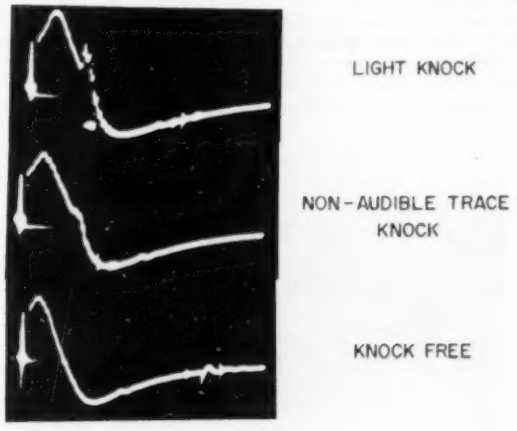

FIG B

the bottom one can be clearly seen, and the middle one shows the case where the trace knock was not audible to the tester, although it was nevertheless apparent on the picture.

J. H. Boddy (Mobil Oil Co. Ltd): I did not put myself forward as an expert to talk on this paper and have in fact no contribution of evidence or practical experience such as the two previous speakers have made, but I have to express doubts and disagreement with their wholehearted endorsement of all the authors' conclusions. My doubts are about conclusion 2, in which the authors state: "Standardized test conditions improve the reproducibility of data by eliminating weather variables." Whilst this is a commonsense expectation, I have not found any evidence in the paper to support it. On p. 109 it is stated that the accuracy of ON requirements and fuel ratings is improved by the use of the chassis dynamometer, and it can only be presumed that there is some evidence to support this which does not appear in the paper. It is presumed that they have carried out tests over a range of temperatures and humidities and shown the effects of these variables. If this is so it would be interesting to know the nature of these effects and whether they can support or dispute the humidity and temperature corrections used by the Co-operative Octane Requirement Committee for road test data.

However, bearing in mind that they should have such data, I would like to ask the authors whether Figs 5 and 7 incorporate any correction factors for humidity and temperature to adjust the chassis dynamometer conditions to the atmospheric conditions prevailing during each of the road tests. If not, were all the humidity and temperature conditions during the tests stabilized by nature to make possible the wonderful correlation exhibited by these figures? Alternatively, I am led to the conclusion that humidity and temperatures are somewhat insignificant variables in car octane requirement and fuel rating tests and have to query the authors' second conclusion that reproducibility is improved by eliminating the weather variable.

J. Tubman: The remarks Dr Moss made and the description of his instrumentation were very interesting. There has always been a desire to instrument for knock, but as we saw in the figure depicting the instruments, this can be rather complex, particularly if one considers a programme involving fuel ratings or octane requirement surveys in a large number of cars, not only at one's own research centre but also at associated centres overseas. I cannot imagine all that equipment being used.

We also still believe that customer reaction is the ultimate measure; therefore, from the marketing viewpoint, the ear is still the best.

In our experience, knock which at high speed is just audible to our trained observers will not result in damage. Therefore we believe that inaudible knock will not hurt the engine or the customers.

We are, however, in favour of a certain amount of this instrumentation, because undoubtedly it is very valuable for fundamental work, particularly on abnormal combustion, and in this connexion we use equipment very similar to that which Dr Moss showed.

We have found, when using a spark plug pick-up, that the sensitivity of the pick-up to knock is varied and differs in certain engines. In an extreme case, it will not detect knock.

Whilst still thinking of this instrumentation, considerable experience is necessary on each individual engine to which this type of instrumentation is applied before reliable results can be obtained.

We have also found that considerable difficulty can be encountered when using the same type of spark plug pick-up as Dr Moss has shown and we think this is most probably due to gas resonance in the indicator passages.

Reverting to the argument of ear *v.* electronic instrumentation, we suggest that unless the electronic equipment used measures the knock on an absolute scale the aim has been lost. Ideally, this instrumentation must provide better accuracy and an irrefutable rating, without the need of experienced personnel in continual attendance. Visual presentation alone is not sufficient, since assessing and interpreting those diagrams calls for wide experience and the answer is still largely biased, because whilst watching the pressure or the rate of change of pressure diagram, the ear is listening.

I wonder whether in fact Dr Moss uses this equipment for routine octane requirement determinations on the road? One final point which interests us is: does he find it necessary to cool the PZ 6 pick-up to protect it from the heat of the engine?

K. Arter (Esso Research Ltd): I do not quite know the answer to the last point. With regard to the extent of its use, this equipment is relatively new, and it has not entirely displaced rating by ear at this time. But I do know that Dr Moss is pleased with it so far.

J. F. Manger: No correction factors have been applied to the data presented in Figs 5 and 7. The octane requirement determinations and fuel ratings on the road were obtained over a period of some months and, of course, during this time wide variations of temperature and humidity were experienced. However, we adhere to certain standardized test procedures, and these require that we do not obtain fuel rating or octane requirement data when the relative humidity is high (in excess of about 90 per cent), as it is when rain is threatening or during and immediately after a rainstorm. When testing fuels on the vehicle dynamometer the ambient air temperature is controlled as nearly as possible to 70° F, although in the height of summer it sometimes rises above that value. Because of this temperature

control, the range of humidity experienced on the dynamometer is quite small. Barometric pressure we can, of course, do nothing about.

We have done some work to find out whether we can improve the reproducibility of ratings using the same fuel and the same car and, again, of octane requirements, by applying a correction factor. We have applied all the correction factors of which we have knowledge, but so far we have not found a correction formula which does not give worse results than the uncorrected data.

However, there is evidence to show that variations in atmospheric conditions affect octane requirements and fuel ratings. Because of this we claim that the more stable air temperature and humidity conditions which apply to tests made on the vehicle dynamometer do improve test reproducibility.

K. Arter: I should like to add a few comments of my own, rather as a member of sub-committee F than as a member of any particular oil company staff.

Technically, I think the most interesting and novel feature of the Sunbury design is the electronic simulation of inertia, which should greatly improve the flexibility of the test plant. Many other laboratories are using a combination of a truck axle and centrifugal fan. I believe the credit for the initial concept is due to Neil MacCoull of the Texas Oil Company. I recall seeing

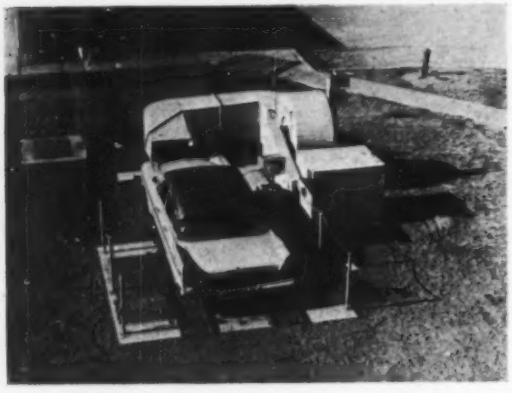

FIG C

his original vehicle dynamometer at Beacon, New York, as far back as 1938. He was fortunate in having only to cater for a narrow range of American car sizes. In Europe we have to cope with vehicles weighing anything from 12 cwt to well over 2 tons.

Any form of scheduled road testing on the public highway must be ruled out for the future, and there is already a pressing need for a simpler, and therefore cheaper, test rig for routine knock ratings and similar work, including perhaps the accumulation of engine deposits. I would therefore like to invite the authors' views on how far we could go in this direction.

For example, is it really necessary to measure horsepower? The torque or horse-power measured by the authors' dynamometer is subject to tyre losses of unknown magnitude, and therefore not necessarily precise. Why not use intake manifold vacuum as a measure of engine load? If this is done, a simple arrangement of belts and pulleys could be used to couple the rolls to the fan.

Do we really need an expensive building to house the rig? An outdoor rig eliminates heat dissipation problems, which are often troublesome in a closed test room.

Fig C illustrates more or less what I have in mind. Everything except the rolls is above ground. The centrifugal fan, at the top right, absorbs constant speed, level road load, and provides a range of loadings for different-sized cars by means of dampers on the inlet and outlet sides. Car inertia is provided by the rolls, supplemented by inertia weights on an intermediate

FIG D

shaft driven by V-belts. Additional loadings to simulate hill-climbing can be applied by an industrial type of disk brake, with suitable controls. Our laboratories in the U.S.A. built this particular rig in 1957 as a prototype, to decide whether test car mileage accumulation and road octane rating work could be transferred to relatively inexpensive outdoor equipment.

It proved so successful that it grew into the rig shown in Fig D. Here the greatest single economy is being

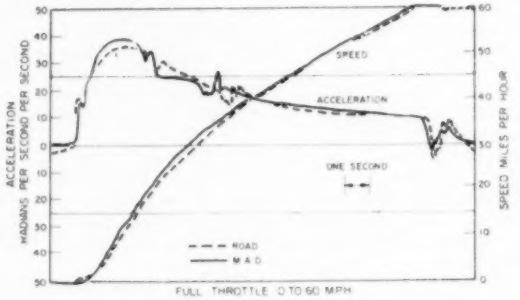

FIG E

able to accumulate mileage 24 hours a day under realistic driving conditions without a man in the driving seat. He is replaced by a magnetic tape simulator, which has been described in an SAE paper.*

Fig E shows how closely the simple outdoor rig simulates full throttle acceleration, and Fig F illustrates the good correlation between ON determinations on the road

* Lewis, O. G., *et al.* "An Eight-Lane Dynamometer Highway." SAE Paper 69U, June 1959.

and the test rig, using the three different procedures. I want to emphasize that, to-night, I am thinking of the simplest possible rig as a supplementary tool, and not as an alternative to the splendidly expensive research plant which has been built at Sunbury. I appreciate, too, that they have a special noise problem there, requiring the construction of a soundproof house. My rig would serve the same sort of purpose, perhaps, as the Petter engine test unit, which the IP has already sponsored for routine tests on crankcase oils. To retain its inherent

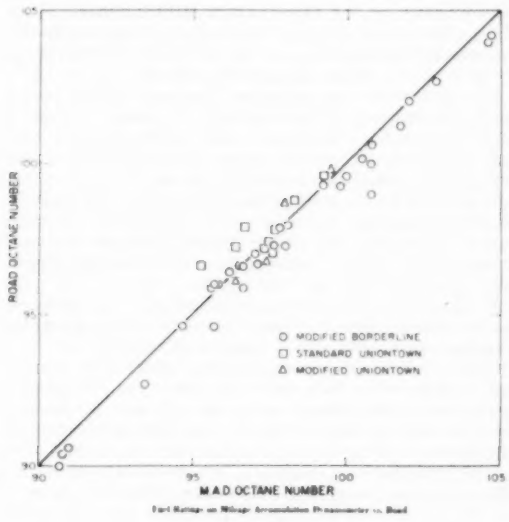

FIG F

simplicity, the rig might have to be designed for a somewhat narrower range of popular car sizes. The authors are better able to pronounce on this than I am. Given enough support, I feel sure that a batch of such car test rigs could be made at a low enough price to appeal to car manufacturers and oil companies alike, and the scope of our co-operative work would benefit accordingly.

J. Tubman: Mr Arter asks whether it is necessary to measure horse-power or torque. It really depends on the range of work attempted on a vehicle dynamometer. Certainly intake manifold depression can be used to indicate the engine load and is very useful for reproducing road conditions.

I wonder if perhaps there is some misunderstanding about our apparatus for driving wheel torque measurement. Our plant, without the dynamatic dynamometers, is essentially only rolls and belting and centrifugal fan. On a plant such as this we would measure our torque in exactly the same way as we do now, by means of a torque arm on the roll axle. We would still not have to rely on manifold depression alone.

K. Arter: I feel that is a very expensive part of the whole equipment.

J. Tubman: Not the measurement of the driving wheel torque. The dynamatic dynamometers simply serve to give us the additional inertia over and above that of the plant, and to simulate hill-climbing.

Do we need an expensive building? If controlled atmospheric conditions are not required, and the plant is to be used only for mileage accumulation and road octane requirement work, then outdoor equipment such as that we have just seen is adequate. I would add a modification for the U.K.—it should have a roof! I remember, as a matter of fact, reading with great interest the SAE paper on the eight-lane dynamometer highway. Any universal rig, such as Mr Arter suggested, would be difficult to design for the European market, due to the wide range of car sizes, but we do feel that an enormous amount of work could be obtained on such a plant, with, say, five or seven changes of inertia. There may be difficulty in convincing people of the validity of the results if the car inertia is not exactly matched, and a good deal of experimental work would be needed to overcome this doubt. Finally, we have recently installed a roller dynamometer at Sunbury and it will be used primarily for car performance checks and simple tests not requiring controlled atmospheric conditions. In this way it will serve in taking some of the work load off the vehicle dynamometer.

A. Malins (Associated Ethyl Co. Ltd): How important is the true reproduction of road acceleration on the plant, as far as road ratings and octane requirements are concerned, and have the authors satisfactorily measured road load horse-power on the dynamometer? If so, what parameters have been determined on the road and subsequently reproduced on the dynamometer to enable this power to be measured? And what has been the correlation of these parameters to the road dynamometer?

J. Tubman: We think it is quite important to reproduce the acceleration accurately and we do. I cannot think of many cases where we have knowingly been inaccurate, and therefore I cannot answer you very well on that point. We have not purposely set up inaccurately to obtain a result.

I think I can answer the other points more easily by giving an idea of the setting up of a vehicle on our plant, and in that way I will be able to tell you how we reproduce measurements we take from the road.

Before any vehicle is driven on to a dynamometer for the first time we obtain certain basic data on the road. These are: manifold depression at steady speeds; fuel consumption at steady speeds; accelerations through the speed range—10 to 30, 20 to 40, 30 to 50, etc; and then an overall acceleration time of 0·3 to 0·8 of the vehicle's maximum speed. We then set the car upon the plant and match as many of these conditions as possible. As you already know from the paper, the centrifugal fan on our plant absorbs the power developed by the car at steady speeds. The power absorbed by the fan can be varied by adjusting the fan outlet area. Therefore we are in the position of being able to get a reasonable match of the road data at each speed. This means that we may have a different fan outlet area for each speed, during steady speed tests, but since most of the work on our plant involves accelerations it is necessary to choose one fan outlet area only. This is chosen from the values required at steady speeds, and is generally the area which best satisfies the mid-speed range of the car. If the equivalent inertia weight of the vehicle is no more than that of the plant, we can then match acceleration times through the speed range with reasonable accuracy with this one fan outlet area setting. If the vehicle has an equivalent inertia greater than that of the plant, it is necessary for us to set a factor corresponding to the weight of the vehicle on a potentiometer on the electronic load control panel, so that for the acceleration work the total inertia of the system will match that of the test vehicle.

With regard to the correlation, in general we match manifold depressions and obtain fuel consumption within 3 per cent of the values obtained on the road, using the individual fan outlet area for each speed. This error can be up to about 5 per cent when the fan outlet area is kept at one value. The acceleration time of 0·3 to 0·8 of a vehicle's maximum speed can be and is matched exactly and, generally, the acceleration times of the speed ranges within this overall acceleration will be within 5 per cent of the road values. I think you will agree that the correlation shown in the paper would not be possible unless the car dynamometer performance was reasonably well matched against the road performance.

We measure rear wheel torque by setting the vehicle up to the parameters just discussed. The power that we measure at the rear wheels on the plant must be very close to the correct road load power.

A. Malins: Suppose that in your steady speed road load, you take three primaries on the road: manifold depression, road load speed, and vehicle speed. Can you measure and correlate all three together on the plant?

J. Tubman: Yes. That is within 3 per cent, which is pretty good. I think you will agree, from your own experience, that when obtaining manifold depression and fuel consumption on the road, repeatability within 3 per cent is not easy.

L. Thomas ("Shell" Research Ltd): Mr Arter's comments about the SAE paper by Neil MacCoull were very appropriate. That paper is almost a classic on the subject and is of the utmost value to anybody designing a vehicle dynamometer. MacCoull acknowledged the inspiration he had received from the dynamometer built by Professor Lockwood in 1907, so we have not travelled very far.

The curves given in Fig 3 are most interesting. I feel that the ability to reproduce road acceleration times is the acid test of a vehicle dynamometer. When this is accomplished, one can be certain that the road loads are well simulated at all speeds. When planning the Thornton Research Centre vehicle dynamometer we realized that no matter how well we reproduced each road load, and controlled them through the speed range, our efforts would be of no avail if we tolerated stray uncontrolled loads inherent in the equipment. Mechanical friction was rather unpredictable. This was one reason for rejecting our original plan to use eddy current brakes. We selected a dc absorption system which enabled us to supply controlled power to the equipment to overcome the mechanical friction. In this way the vehicle was relieved of this additional load. When commissioning the plant we found that our fears had not been groundless. The plant friction is equivalent to about 40 lb of vehicle tractive effort. Put another way, the equipment has an inherent gradient of 1 in 50 when testing a vehicle weighing 2000 lb. This load seriously affected accurate control of level road loads through the speed range until we used the compensation provided. I understand from what Mr Tubman has just said that the results shown in Fig 3 were obtained from trial and error runs. We find that we can reproduce acceleration times after one, and perhaps two, trial runs.

Mr Tubman, when answering a previous speaker, referred to the need to alter the fan load at various speeds, to reproduce level road loading at various speeds. MacCoull gave evidence that the air resistance component of the level road load has the same characteristic with varying speed as the load to drive a centrifugal fan. Other research workers have confirmed this. We find that a single setting of the centrifugal fan, the addition of a load equivalent to front wheel rolling resistance, and the friction compensation previously mentioned impose a load representative of the load throughout the speed range. I suggest that with the Sunbury vehicle dynamometer the sum of the centrifugal fan load and the plant's mechanical friction does not follow the characteristic of level road load changes with speed.

As with the Sunbury dynamometer we add to the inherent mass of the equipment a load, applied electrically, proportional to the extra weight of the vehicle and the rate of acceleration. Since we use a dc system, we are able to reproduce deceleration rates.

I understand that, with the Sunbury dynamometer, the air is blown on to the vehicle at a somewhat lower velocity than the simulated speed of the vehicle. We went to a deal of trouble to select a fan which automatically provides the air at a velocity within 1½ mph of the simulated vehicle speed. We blithely thought that our efforts were repaid by the accurate correlation of underbonnet temperatures. Since Sunbury do as well as is shown in Table I, it would appear that the air velocity is not as significant as we thought.

Mr Lamarque mentioned correlation of transmission temperatures. We find that rear axle oil temperatures correlate well. We have done a number of tests involving 14 hours non-stop running at 80 mph without any cooling other than from the main fan. Rear axle temperatures are always quite normal, and no parts of the transmission have suffered. My opinion is that the transmission parts do not get the relative passage of air on the road that one might expect, due to the sheltering effect of their positions. The axles which are part of our dynamometer equipment were fitted with oil circulation and cooling systems because we considered the oil would be overheated due to the absence of air flow. In fact, the oil temperatures rarely exceed 50° C, without recirculation and cooling.

Mr Tubman said, in answer to Mr Arter, that their building is only as elaborate as is necessary when one requires temperature control. Our arrangements for temperature control are crude by comparison. We use the entrance doors as electrically-operated dampers, so proportioning the ratio of rejected and recirculated air. We find it a satisfactory system.

We have had some experience of front wheel drives. While driving in top gear the vehicle is quite stable and no special measures are adopted. When driving in bottom gear and at near full-throttle, the tractive effort is near the limit of adhesion of the tyres, and wheel slip occurs and causes the wheels to steer. We lock the steering and ballast the car.

The paper mentions the safety trip which switches off the vehicle ignition when a fault occurs. This is not applicable of course to diesel-engined vehicles. I presume that Sunbury relies, as we do, on the driver reacting to an alarm in these cases.

During vapour lock tests we find it necessary to maintain the recirculation of air through the main fan during the 15 minutes idle period, to prevent the test room temperature from dropping. The engine is stopped with the gear in neutral so that the equipment can be motored. I shall be interested to know whether Sunbury follows this procedure.

We seem to follow a different policy regarding instrumentation. It surprises me that Sunbury make so many connexions to the vehicle. We aim to spend no longer than 10 minutes preparing a car for running. The only inter-connexion we make is to the vehicle ignition. Any

special instrumentation required is self-contained in the test vehicle. We find that connexions to control room throttle controls and spark advance controls are time-consuming and rarely required. While Sunbury seem to have these installed as permanent features of their control panel, I would like to know whether they are connected to the vehicle as a routine measure, or only when the test procedure demands them.

J. F. Manger: Various power absorption systems were considered when the Sunbury dynamometer was being planned, and it was concluded that, on balance, a specially-designed centrifugal fan, together with eddy current brakes controlled by a suitable electronic circuit, would be the most suitable arrangement.

It is quite true that the steady speed load provided by such a system is made up of fan load and general plant friction. We find that this power absorption characteristic allows us to simulate quite closely, at one fan setting, the level road power requirements of the majority of vehicles in the design range of the plant.

For a given power input the rate of acceleration of the plant is controlled by fan load, plant friction and general losses, plant inertia, and eddy current brake load. This latter component is a variable depending upon the "car weight" setting in the circuit controlling the brake field current. This electronic circuit allows us to compensate for losses in the plant by applying only the additional load required to control the rate of acceleration. We are therefore able to reproduce the acceleration performance of most cars. Exceptions are when the required rate of acceleration is low. Under these conditions the rate of acceleration is controlled entirely by fan load, plant friction, and plant inertia, the eddy current brakes being unable to provide the "negative load" required.

The correlation between road and vehicle dynamometer that we have obtained over the last five years suggests that the Sunbury dynamometer steady speed and acceleration power absorption characteristics are generally as required to simulate road conditions.

Deceleration is available through the eddy current brakes and operated as required by a flick switch; deceleration is produced at the same rate as in a car on the road.

We have measured the air velocity at the duct outlet and have found it to be 5 per cent of the speed of the car. This is nominally correct, in our opinion, particularly bearing in mind that the air speed is not constant over an outlet of this type.

On transmission temperatures, we have no comment; we get them higher on the dynamometer than on the road. There is very little flow of air under a car on the dynamometer, and to get down to road temperatures we must supply more air from some independent source.

Although the dynamometer building may appear elaborate, it is not unnecessarily so. A point that we particularly have to bear in mind at Sunbury is the proximity of other laboratories and private houses. We often run through the night on this plant, and it is therefore essential that noise transmission be reduced to a low level, even at the expense of a more elaborate building.

As far as the front wheel drive car is concerned, perhaps we had different drivers, but our cars (of a similar type, I am sure) tend to veer in top gear only on the overrun. I would expect that the handling differences experienced are due to different methods used for securing the vehicle to the dynamometer floor.

Diesel engine cars must of course, be stopped by the driver in response to a warning, as there is no ignition to cut off.

When doing vapour lock tests, the ambient air temperature is kept up during soak by re-circulating the air through the heater fans between the dynamometer test room and the fan chamber.

Cars which require instrumentation are fully instrumented for use either on the road or on the dynamometer, and all that has to be done is to connect a multi-pin socket in the car with a plug in the dynamometer bay. On cars used for octane requirement survey data there is normally no instrumentation. Throttle and spark advance control connexions are not usually made for fuel ratings or octane requirements.

I would just like to add that even with our apparent elaborate instrumentation, our cars can be ready for testing within 15 minutes.

L. Thomas: Including duct setting?

J. Tubman: Yes, for normal work. If we wish to carry out engine performance work remote from the car, then it takes a little longer to connect up.

The meeting then closed with a unanimous vote of thanks to the authors.

THE EFFECT OF ACTIVATED CHARCOAL ON THE CLOUD POINT, POUR POINT, AND SULPHUR CONTENTS OF GAS OIL *

By F. A. INKLEY † and A. E. STANDAGE †

INTRODUCTION

THE adsorbent effect of activated charcoal has been previously investigated both for hydrocarbons [1,5] and sulphur compounds.[6] Breshchenko [1] reduced the cloud and pour points of an aviation oil by passing it over activated charcoal. Spengler and Hauf [5] preferentially adsorbed the higher molecular weight compounds from solutions of waxes in hydrocarbons using medicinal charcoal. Wolff and Hill [6] describe a process for removing sulphur and aromatics from hydrocarbons using active charcoal impregnated with alkali metals or oxides.

This paper describes laboratory experiments carried out to study the effect of an untreated, readily available activated charcoal on the cloud point, pour point, and total and mercaptan sulphur contents of a typical Middle East gas oil. The experimental methods used are not believed to have been previously reported in the literature. No attempt was made to carry out hydrocarbon type analysis, as this was beyond the scope of the programme laid down for this work.

MATERIALS AND PROPERTIES

The gas oil used was a typical gas oil obtained from a Middle East crude, and some inspection data are given in Table I. The activated charcoal, full description " Activated charcoal for decolorizing purposes," was supplied by British Drug Houses Ltd. London, and was vegetable in origin. The ash from it contained primarily calcium, silicon, aluminium, iron, magnesium, and phosphorus, with sodium and potassium present in minute amounts. Physical data for the charcoal are shown in Table II. The

TABLE I

Inspection Data on Gas Oil

Specific gravity at 60° F/60° F	0·867
Distillation test	
IBP, °C	251
2% volume recovered at, °C	268
5% volume recovered at, °C	274
10% volume recovered at, °C	280
20% volume recovered at, °C	288
30% volume recovered at, °C	295
40% volume recovered at, °C	303
50% volume recovered at, °C	310
60% volume recovered at, °C	316
70% volume recovered at, °C	324
80% volume recovered at, °C	333
90% volume recovered at, °C	345
Fbp, °C	379
Recovery, %	99
Total sulphur, % wt	1·66, 1·61, 1·66
Mercaptan sulphur, % wt	0·0146, 0·0150
Aniline point, °C	69·3
Pour point (ASTM), °F	30
Cloud point (ASTM), °F	26
Cloud point (micro-method), °F	27

TABLE II

BDH Activated Charcoal—Physical Data

BET specific surface area (S), m^2/g	1117
Specific micropore volume (V) (pores $\leqslant$ 300 Å dia), ml/g	0·93
Average micropore diameter ($\bar{d}$), $\left(\bar{d} = \frac{4V}{S} \times 10^4\right)$, Å	33
Loss on degassing in determining above quantities, % wt	11·8
X-ray diffraction data	Charcoal gave a very weak diffraction pattern which consisted of only two very broad weak diffuse bands which did not correspond to the spacings of graphite
Residue on ashing (850° C), % wt	4·7

Sieve analysis

Particle range, μ	Fraction weight, %
>251	0·2
251–211	0·3
211–152	32·2
152–89	27·0
89–76	26·8
76–44	10·9
<44	2·7

Note: Degassing conditions. Approx 1 hr, 120° C, 10^{-3} mm Hg.

silica gels were supplied by L. Light, Colnbrook, Berkshire, and were " Davison " grades 912 and 70. Physical data are shown in Table III.

EXPERIMENTAL EQUIPMENT AND PROCEDURE

Five laboratory experiments were carried out. In each the gas oil, untreated or treated (method described later), was forced slowly through a compacted column of untreated activated charcoal in order to

* MS received 6 December 1960. † The British Petroleum Co Ltd, BP Research Centre, Sunbury-on-Thames, Middlesex.

reach adsorption equilibrium and a continuous series of samples was taken.

TABLE III

Silica Gels—Physical Data

	"Davison" silica gel grade 912	"Davison" silica gel grade 70
BET specific surface area (S), m^2/g	711	272
Specific micropore volume (V) (pores < 300 Å dia), ml/g	0·38	1·12
Average micropore diameter ($\bar{d}$) $\left(\bar{d} = \frac{4V}{S} \times 10^4\right)$ Å	21	164
Loss on degassing in determining above quantities, % wt	3·0	3·05

Note: Degassing conditions. Approx 1 hr, 120° C, 10^{-3} mm Hg.

Experiments 1 and 2

These experiments were identical and were carried out simultaneously on two sets of identical apparatus.

The mainly glass apparatus used in these experiments is shown in Fig 1. The apparatus was designed

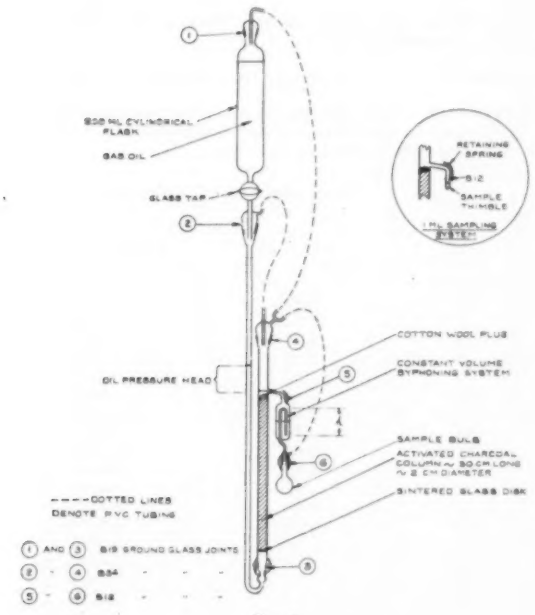
500 ML CYLINDRICAL FLASK
GAS OIL
GLASS TAP
OIL PRESSURE HEAD
RETAINING SPRING
SAMPLE THIMBLE
1 ML SAMPLING
COTTON WOOL PLUG
CONSTANT VOLUME SIPHONING SYSTEM
SAMPLE BULB
ACTIVATED CHARCOAL COLUMN ~ 30 CM LONG ~ 2 CM DIAMETER
SINTERED GLASS DISK
DOTTED LINES DENOTE PVC TUBING
① AND ③ B19 GROUND GLASS JOINTS
② · ④ B34 · · ·
⑤ · ⑥ B12 · · ·

FIG 1

DIAGRAM OF TOTALLY ENCLOSED GLASS ADSORPTION APPARATUS

to be totally enclosed so as to prevent loss of vapours, particularly from light ends, and to permit the gas oil to contact only glass or activated charcoal. For ease of assembly and operation the apparatus was constructed in sections, these sections being joined by means of ground glass joints held together, wherever necessary, by retaining springs. A thin smear of gas oil was used to seal the joints and to prevent sticking. PVC tubing ¼-inch id was used so as to equate air pressure in the enclosed system.

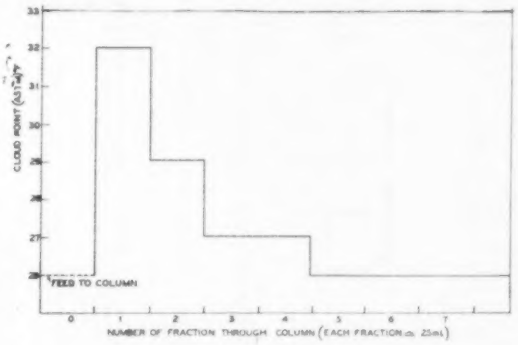

FIG 2

CLOUD POINT OF A GAS OIL AFTER PASSING THROUGH A COLUMN OF ACTIVATED CHARCOAL (Experiment 2)

The adsorption column had an overall length and internal diameter of about 46 cm and 1·6 cm respectively. A fine sintered glass disk supported the activated charcoal column, which was about 29 cm long. The side arm to the sampling system came off about 35 cm from the bottom of the adsorption column.

In general, the dimensions of the apparatus are not critical. The only section of the apparatus containing a critical dimension is the constant volume siphoning system. The height h shown in Fig 1 is critical because the volume of oil automatically transferred to the sample bulb is dependent on this value.

The oil pressure head, and hence flow rate, was easily controlled by setting the glass tap to allow gas oil to drip from the 500-ml cylindrical flask oil reservoir.

In Experiments 1 and 2 the charcoal charge weighed about 25 g. The rate of flow of the gas oil was adjusted to about ¼ ml/hr by varying the head of oil (see Fig 1). Samples of approximately 25 ml were taken automatically by means of the constant volume siphoning system, and selected samples were chosen for cloud point, total sulphur content, and mercaptan sulphur content determinations.

The cloud point data are given in Table IV, and shown graphically in Fig 2. Total sulphur content and mercaptan sulphur content of the samples from Experiment 1 are given in Table V and shown diagrammatically in Fig 3.

Experiment 3

The apparatus used was essentially the same as that used in Experiments 1 and 2, except that the constant volume siphoning system was replaced by

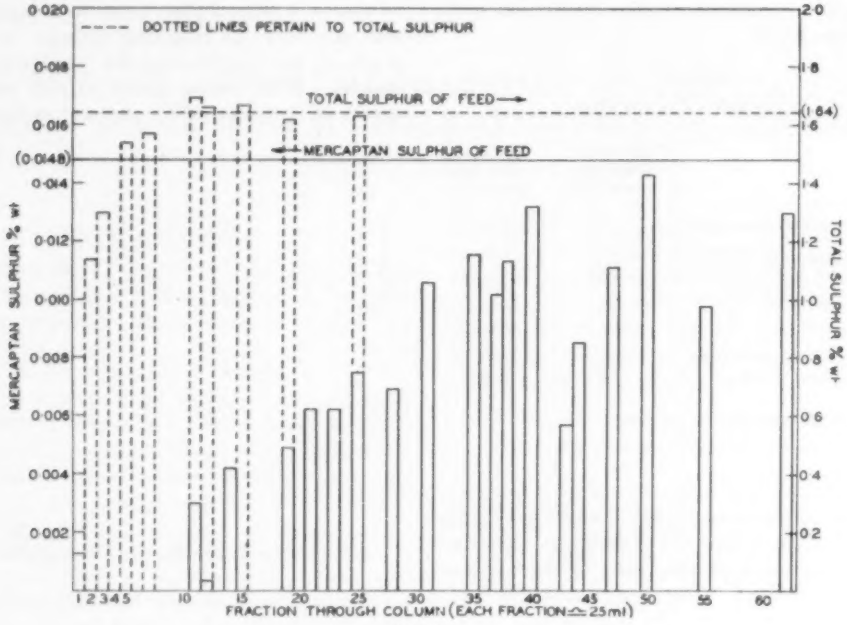

FIG 3

TOTAL SULPHUR CONTENT AND MERCAPTAN SULPHUR CONTENT OF A GAS OIL AFTER PASSING SLOWLY THROUGH A COLUMN OF ACTIVATED CHARCOAL (Experiment 1)

a small sample thimble as shown in the inset diagram of Fig 1. The flow rate was reduced to about 1 ml/day, and a series of samples of approximately 1 ml each was taken. The charcoal charge was about 25 g as before.

The results of cloud and pour point determinations

TABLE IV

Experiments 1 and 2. Cloud Point of a Gas Oil after Passing Slowly through a Column of Activated Charcoal

Fraction	Cloud point, °F ASTM	
	Experiment 1	Experiment 2
1	—	33
2	—	29
3	—	27
4	—	27
5	—	26
6	26	26
7	—	26
8	26	26
10	27	—
13	26	—
17	26	—
24	26	—

Note: 1. Charcoal charge in column ≏ 25 g.
2. Flow rate of gas oil through column ≏ 1/3 ml/hr.
3. Volume of each fraction ≏ 25 ml.
4. ASTM method modified to give results to the nearest degree.

TABLE V

Experiment 1. Total Sulphur Content and Mercaptan Sulphur Content of a Gas Oil after Passing Slowly through a Column of Activated Charcoal

Sample	Total sulphur, % wt	Mercaptan sulphur, % wt
Feed	1·61, 1·66	0·0146, 0·0150
Fraction		
1	0·130	<0·0001
2	1·14	<0·0001
3	1·30	<0·0001
5	1·54	<0·0001
7	1·57	<0·0001
11	1·69	0·0029
12	1·66	<0·0003
14	—	0·0042
15	1·67	0·0032
19	1·62	0·0049
21	—	0·0062
23	1·65	0·0062
25	1·63	0·0075
28	Not determined	0·0069
31		0·0106
35		0·0115
37		0·0102
38		0·0113
40		0·0132
43		0·0057
44		0·0085
47		0·0111
50		0·0143
55		0·0098
62		0·0130

Note: 1. Charcoal charge in column ≏ 25 g.
2. Flow rate of gas oil through column ≏ 1/3 ml/hr.
3. Volume of each fraction ≏ 25 ml.

TABLE VI

Experiment 3. Cloud Point and Pour Point of a Gas Oil after Passing through a Column of Activated Charcoal

Sample	Cloud point (micro-method), °F	Pour point (micro-method), °F	Sample	Cloud point (micro-method), °F	Pour point (micro-method), °F	Sample	Cloud point (micro-method), °F	Pour point (micro-method), °F
Feed	27	20, 30	Fraction			Fraction		
			25	35	35	51	28	—
Fraction			26	34	—	52	29	—
1	27, 29	30	27	32	—	53	28	—
2	28	30	28	32	—	54	29	—
3	29	30	29	30	—	55	30	30
4	29, 29	30	30	30	35	56	28	—
5	29	30	31	29	—	57	28	—
6	31, 33	35	32	31	—	58	29	—
7	31	30	33	31	—	59	29	20
8	32	35	34	30	—	60	—	—
9	33	35	35	31	30	61	—	—
10	35	35	36	31	—	62	—	—
11	34	30	37	30	—	63	29	—
12	34	40	38	31	—	64	—	—
13	35	40	39	31	—	65	—	—
14	34	35	40	30	30	66	—	25
15	34	35	41	30	—	67	29	—
16	34	35	42	31	—	68	—	—
17	35	40	43	30	—	69	—	—
18	35	40	44	29	—	70	28	—
19	37	—	45	29	30	71	—	—
20	37	40	46	30	—	72	—	—
21	36	—	47	30	—	73	—	20
22	36	—	48	—	—	74	28	—
23	35	—	49	—	—			
24	35	—	50	29	—			

Note: 1. Charcoal charge in column ≏ 25 *g*. 2. Flow rate of gas oil through column ≏ 1 ml/day. 3. Volume of each fraction ≏ 1 ml.

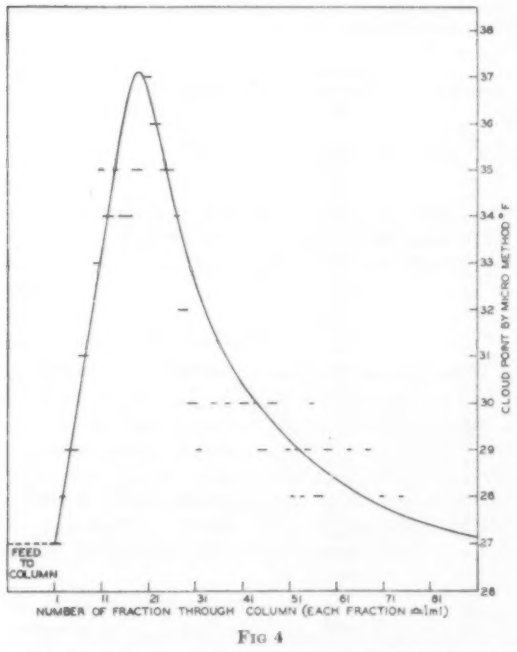

FIG 4

CLOUR POINT OF A GAS OIL AFTER PASSING THROUGH A COLUMN OF ACTIVATED CHARCOAL (Experiment 3)

on selected samples are given in Table VI, and the cloud point values are shown graphically in Fig 4.

Experiment 4

The apparatus used was the same as that used in Experiment 3. The gas oil was treated with silica gels to reduce the aromatic content. 1·1 litre of gas oil was treated by stirring for 5 hours with 500 g of "Davison" 912 grade silica gel. The resultant slurry was filtered using a Buchner funnel and flask. The filtrate was stirred for 5 hours with another 500 g of fresh "Davison" 912 grade silica gel and the resultant slurry filtered as before. The process was repeated a third time. Finally, the filtrate from the third treatment was stirred with 150 g of "Davison" 70 grade silica gel for 6 hours. The resultant slurry was filtered as before to yield 150 ml of "de-aromatized" gas oil. Mass spectroscopic analysis of the untreated and treated oils showed a reduction in the C_{20} aromatic peak height from 70 to 11 mm.

As for the previous experiments, the charcoal charge was about 25 g. The flow rate was adjusted to about 1 ml/day as in Experiment 3, and a series of samples of approximately 1 ml each was taken.

The results of cloud and pour point determination on selected samples are given in Table VII and the cloud points are shown graphically in Fig 5.

Q

TABLE VII

Experiment 4. Cloud Point and Pour Point of a Silica Gel "De-aromatized" Gas Oil after Passing through a Column of Activated Charcoal

Sample	Cloud point (micro-method), °F	Pour point (micro-method), °F	Sample	Cloud point (micro-method), °F	Pour point (micro-method), °F
Feed	35, 36	40	Fraction 30	39	40
Fraction			31	39	—
1	15	15	32	40	—
2	16	20	33	39	—
3	19	20	34	39	—
4	21	10	35	39	40
5	26	—	36	40	—
6	28	—	37	—	—
7	30	—	38	39	—
8	32	—	39	38	—
9	33	—	40	38	45
10	35, 37	—	41	38	—
11	37	—	42	39	—
12	37	—	43	39	—
13	38	—	44	39	—
14	38	—	45	39	45
15	39	—	46	39	—
16	—	—	47	39	—
17	38	—	48	—	—
18	38	—	49	—	—
19	38	—	50	—	40
20	39	45	51	39	—
21	39	—	52	—	—
22	40	—	53	—	—
23	39	—	54	—	—
24	39	—	55	—	40
25	39	—	56	40	—
26	40	—	57	—	—
27	39	—	58	—	—
28	39	—	59	—	40
29	39	—	60	39	—

Note: 1. Charcoal charge in column ≏ 25 g.
2. Flow rate of gas oil through column ≏ 1 ml/day.
3. Volume of each fraction ≏ 1 ml.

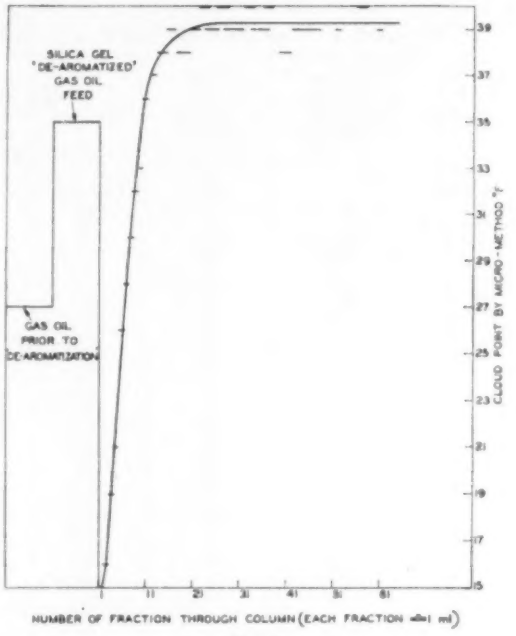
SILICA GEL 'DE-AROMATIZED' GAS OIL FEED
GAS OIL PRIOR TO DE-AROMATIZATION
CLOUD POINT BY MICRO-METHOD °F
NUMBER OF FRACTION THROUGH COLUMN (EACH FRACTION ≏ 1 ml)

FIG 5

CLOUD POINT OF A SILICA GEL "DE-AROMATIZED" GAS OIL AFTER PASSING THROUGH A COLUMN OF ACTIVATED CHARCOAL (Experiment 4)

TABLE VIII

Experiment 5. Total Sulphur Content and Mercaptan Sulphur Content of a Gas Oil after being Forced under 50 psig Pressure through a Column of Activated Charcoal

Fraction	Volume of fraction, ml	Total sulphur, % wt	Mercaptan sulphur, % wt	Fraction	Volume of fraction, ml	Total sulphur, % wt	Mercaptan sulphur, % wt
Feed	—	1·67	0·0162	27	110	1·48	0·0001
				28	83		
1	91			29	110		
2	32			30	78		
3	104	0·20	0·0002	31	564		
4	70			32	72		
5	110			33	110		
6	82	1·38	0·0003	34	71		
7	110			35	110		
8	82			36	72		
9	110			37	110		
10	78	1·37	0·0001	38	190		
11	564			39	564	1·65	0·0006
12	70			40	180		
13	110			41	210		
14	88	1·57	0·0001	42	148		
15	110			43	176		
16	89			44	564		
17	110			45	174		
18	88			46	180	1·66	0·0001
19	110			47	180		
20	85			48	164		
21	564			49	564		
22	71			50	174		
23	110			51	172		
24	75			52	210		
25	110			53	883	1·67	0·0003
26	79						

Note: 1. Charcoal charge in column ≏ 300 g. 2. Flow rate of gas oil through column ≏ 200 ml/day.

Experiment 5

The all-metal apparatus used in this experiment is shown diagrammatically in Fig 6. Untreated gas oil under a pressure of 50 psig of air was forced through the horizontal column, which contained approximately 300 g of activated charcoal. The flow rate was about 200 ml/day.

Table VIII gives details of the volume of all the fractions taken and total sulphur and mercaptan sulphur contents of selected fractions.

Test Methods Used

Cloud and pour point results were generally obtained by micromethods because of the limited volumes of the samples available. Cloud and pour points not obtained by micromethods were obtained by ASTM Standard Method of Test for Cloud and Pour Points, ASTM D97–57. The ASTM method for cloud point was modified to give results to the nearest degree.

Cloud Point by Micromethod

Approximately 0·1 ml of sample was cooled in a specially designed cell, and the temperature at which wax crystals first appeared when viewed through a microscope using polarized light was noted. The sample was cooled using cooled compressed air, the rate of flow of the air being controlled to give a cooling rate of about 1° F/min. The repeatability of the method, probability level undefined, is 2° F.

Pour Point by Micromethod

These determinations were made using a method described by Javes and Liddell,[3] based on a method by Levin, Morrison, and Reid.[4]

Sulphur Determinations

Total sulphur determinations were done using the IP Method of Test IP 107/53. Mercaptan sulphur determinations were done using a modified IP Tentative Method of Test IP 104/53T, the primary modification being in the use of an electrometric determination of end point.

RESULTS OBTAINED

Cloud Point and Pour Point

Experiments 1 and 2 (Table IV and Fig 2) show that when a typical Middle East gas oil is passed through a column of activated charcoal a rise in cloud point occurs at first. Experiment 3 (Table VI and Fig 4) shows that the cloud point rise is a gradual one leading to a maximum value. In all these experiments the cloud point eventually falls to the value of the feed.

Experiment 4 (Table VII and Fig 5) shows that when a "de-aromatized" gas oil is passed through a column of activated charcoal an immediate fall in cloud point occurs. The cloud point then rises until its value exceeds that of the feed. Presumably the value eventually drops to equal that of the feed.

Experiments 3 and 4 (Tables VI and VII) show that changes in pour point occur in an analogous manner to changes in cloud point.

Total Sulphur and Mercaptan Sulphur

Experiment 1 (Table V and Fig 3) and Experiment 5 (Table VIII) show that a reduction in total sulphur and mercaptan sulphur contents occurs when a gas oil is passed through a column of activated charcoal.

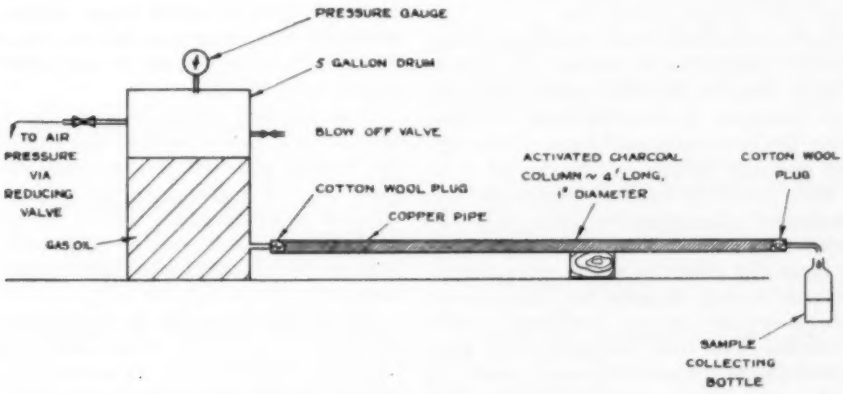

FIG 6

DIAGRAM OF APPARATUS USED IN HIGH PRESSURE ADSORPTION EXPERIMENT

DISCUSSION OF RESULTS

Cloud Point

The adsorptive properties of activated charcoal with respect to hydrocarbons have been discussed in some detail by Breshchenko.[1] Based on this work, an adsorptive sequence for the various hydrocarbon types is derived, which is as follows:

Low molecular weight aromatics (most readily adsorbed), high molecular weight aromatics, high molecular weight saturated straight-chain hydrocarbons, low molecular weight straight-chain hydrocarbons, and branched-chain saturated hydrocarbons (least readily adsorbed). The results will be discussed in the light of this knowledge.

It is convenient in discussing the results to distinguish between theoretical, infinitely small, liquid fractions and the actual liquid fractions obtained experimentally. The former will be referred to as increments and the latter simply as fractions.

When a liquid mixture passes through an adsorption column, provided equilibrium is established, the first increments must comprise the least readily adsorbed components. Therefore, if Breshchenko's sequence is the true one, the first increment of gas oil through the activated charcoal column will be devoid of or deficient in high molecular weight components, and it is not unreasonable to expect the cloud points of these increments to be lower than that of the feed. Because low molecular weight aromatics are adsorbed preferentially, these will displace the initially adsorbed high molecular weight compounds, and ensuing increments of oil from the column will have increasing cloud points. Eventually some maximum value of cloud point will be reached, higher than that of the feed, before the value drops to that of the feed.

The cloud point is essentially a measure of the concentration and solubility of the least soluble components of the hydrocarbon mixture. These components are the high molecular weight compounds, particularly the high molecular weight saturated straight-chain hydrocarbons. The cloud point may be altered in three ways:

1. By altering the concentration of the high molecular weight components, particularly the high molecular weight saturated straight-chain hydrocarbons.
2. By altering the nature of the "solvent" (*i.e.* the remainder).
3. By altering 1 and 2 together.

In an adsorption column, the cloud point changes are explained only by considering a joint effect, *i.e.* by (3) above.

Consider Experiment 3 (Fig 4). Here an untreated gas oil, rich in aromatics, is fed to a charcoal column. The first fraction of 1 ml through the column has the same cloud point as the feed. Presumably this is because the cloud point depressions forecast for the first increments are just cancelled out by the cloud point rises of the other increments comprising the fraction. The charcoal column rapidly adsorbs the low molecular weight aromatics. Decrease in aromatic content causes an increase in the concentration of the high molecular weight components in the oil which has passed through the column, with a consequent increase in cloud point. It is also probable that the removal of low molecular weight aromatics also reduced the solubility of the high molecular weight components in the remainder of the oil. This would also result in an increase in cloud point. When the charcoal is saturated with low molecular weight aromatics no further change in composition of the gas oil occurs, and the cloud point falls to that of the feed. The area bounded by the curve and the horizontal at 27° F in Fig 4 gives a measure of the effect on the cloud point of the removal of the lighter aromatics from *ca* 90 ml of gas oil, the effect being unevenly distributed between the fractions because of different distributions of the other components among these fractions.

Now consider Experiment 4 (Fig 5). The first fraction of "de-aromatized" oil through the column has a cloud point 20° F lower than the feed (which itself is 12° F higher than the original gas oil from which it was prepared). This is due to the removal of high molecular weight compounds, particularly high molecular weight saturated straight-chain hydrocarbons.

The progressive rise in the cloud point of succeeding fractions is due to two effects acting simultaneously. These are the filling up of the adsorbent capacity by high molecular weight saturated straight-chain hydrocarbons and the progressive displacement of these hydrocarbons by the small amount of aromatic hydrocarbons not removed from the feed by silica gel. Eventually a situation prevails somewhat similar to that of Experiment 3 but more complicated by this stripping effect. The net effect is to cause a rise in cloud point above that of the feed. Fractions were not collected to the point where the cloud point equalled that of the feed, but it is reasonable to assume that this fall must inevitably occur. Because of the much lower aromatic content, the amount of gas oil passed before the cloud point rises above that of the feed is much greater than in Experiment 3; in fact, the first 11 fractions on Experiment 4 have about the same mean cloud point (26·6°) as the first fraction in Experiment 3.

Total and Mercaptan Sulphur Contents

There are two notable features about the sulphur removal obtained in this work. The first is the difference in behaviour between mercaptans and other sulphur compounds. Although there is some reduction in total sulphur content at the beginning

of the experiments (Fractions 1–7, Table V, Fractions 1–10, Table VIII), a point is soon reached at which the sulphur removal is negligible. On the other hand, the removal of mercaptan is almost complete at first (Table V, Fractions 1–7, Table VIII, Fractions 1–53), although it thereafter falls rapidly in Experiment 1 (Table V). The second is the great difference in mercaptan removal after the first few fractions between Experiment 1 at atmospheric pressure in a totally enclosed apparatus (Table V) and Experiment 5 under an air driving pressure of 50 psig (Table VIII). In the latter case mercaptan sulphur was almost absent (0·0003 per cent weight) in Fraction 53, after the passage of some 9 l of gas oil over 300 g of charcoal. At this point it can be calculated that some 1·1 g of mercaptan sulphur must have been converted, or nearly 0·004 g/g of charcoal. These facts suggest that the mercaptan removal proceeds by reaction rather than by adsorption, and that the reaction involves oxygen. It is known that free radical carbon atoms exist on the surface of activated charcoal.[2] In the absence of oxygen, mercaptan oxidation might then proceed by Equations (1) and (2) below:

$$R:S:H + (\text{Charcoal})\cdot \longrightarrow (\text{Charcoal}):H + R:S\cdot \quad (1)$$

$$2R:S\cdot \longrightarrow R:S:S:R \quad (2)$$

If oxygen is present, Equations 3 and 4 below might apply:

$$2R:S:H + (\text{Charcoal}):O:(\text{Charcoal}) \longrightarrow R:S:S:R + H:O:H + 2\,(\text{Charcoal})\cdot \quad (3)$$

$$2\,(\text{Charcoal})\cdot + \tfrac{1}{2}O::O \longrightarrow (\text{Charcoal}):O:(\text{Charcoal}) \quad (4)$$

Equation (3) involves carbon radicals which have reacted with oxygen, and Equation (4) provides a means for continuing the reaction.

CONCLUSIONS

1. Activated charcoal selectively adsorbs certain hydrocarbon types from gas oil. This can produce either a raising or a lowering of the cloud point according to the proportion of aromatic types in the gas oil.

2. When a gas oil with an appreciable aromatic content is passed through a column of activated charcoal it undergoes an increase in cloud and pour points, whereas a gas oil of low or negligible aromatic content undergoes cloud and pour point depressions.

3. Reductions in total and mercaptan sulphur contents are produced when gas oils are treated with activated charcoal, particularly when driven under air pressure.

ACKNOWLEDGMENTS

The authors wish to thank Dr J. N. Haresnape for helpful discussions, and the chairman and directors of The British Petroleum Co Ltd for permission to publish this paper.

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[5] Spengler, G., and Hauf, G. *Fette u. Seif., Anstrichmittel*, 1957, **59** (7), 509–14.
[6] Wolff, —, and Hill, — (Standard Oil Co. of Indiana), USP 2,877,176 (1959).

IP STANDARDS — PART IV

Methods for Sampling

A modification has been approved by the Sampling Panel of Standardization Sub-Committee A. The following paragraph is to be added to Section 62(c):

If no defectives are found, there is a 95% certainty that there are less than x% defectives in the consignment. It should be noted that the risk of rejecting an acceptable batch is considerable. For example, if it is considered satisfactory to accept (with 95% certainty) a batch containing no more than 1% defectives, then there is approximately an 80% chance of rejecting a batch with only $\frac{1}{2}$% defectives.

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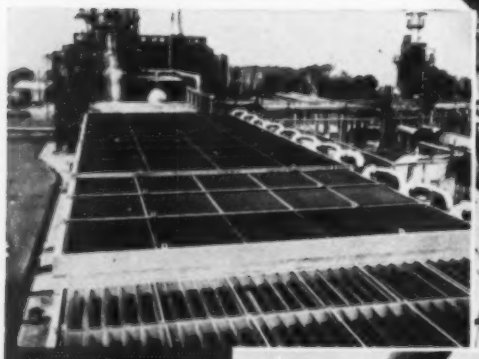

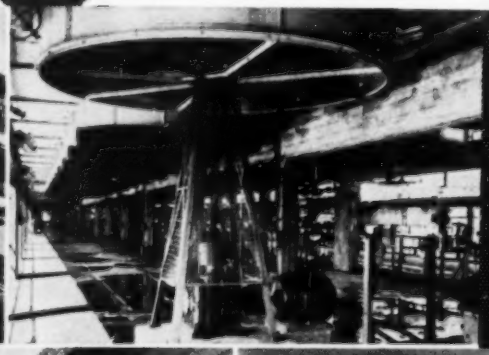

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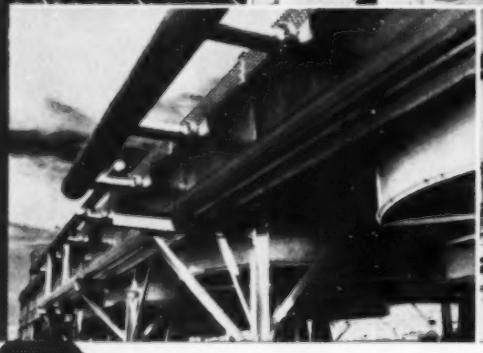

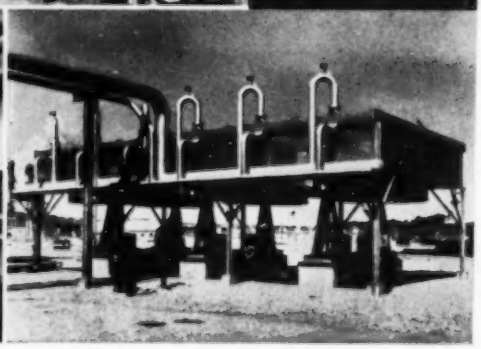

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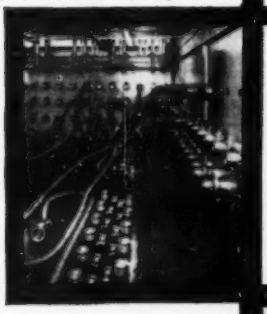

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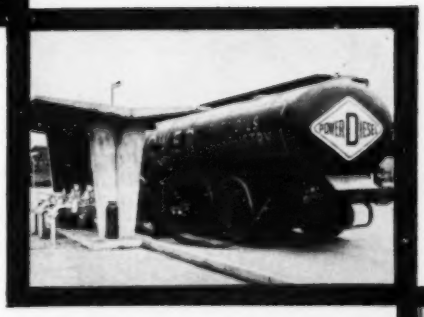

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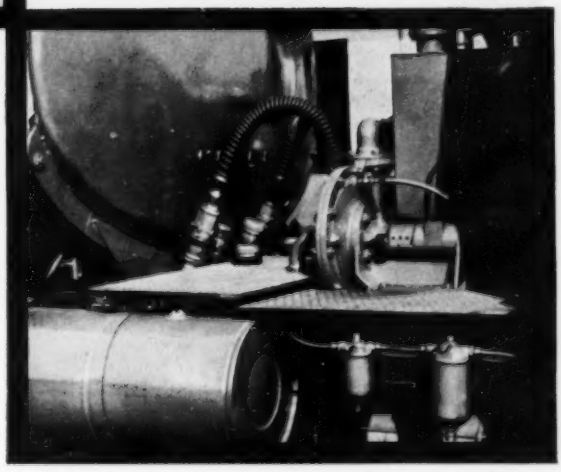

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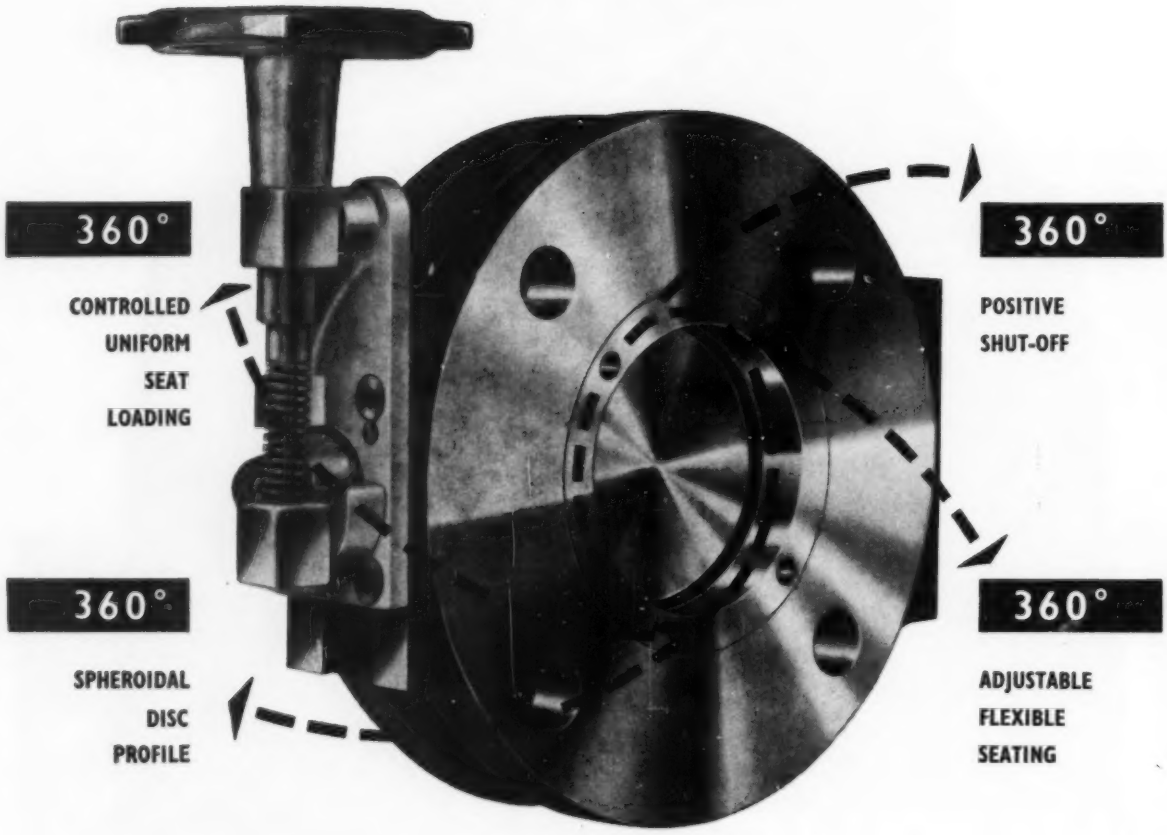

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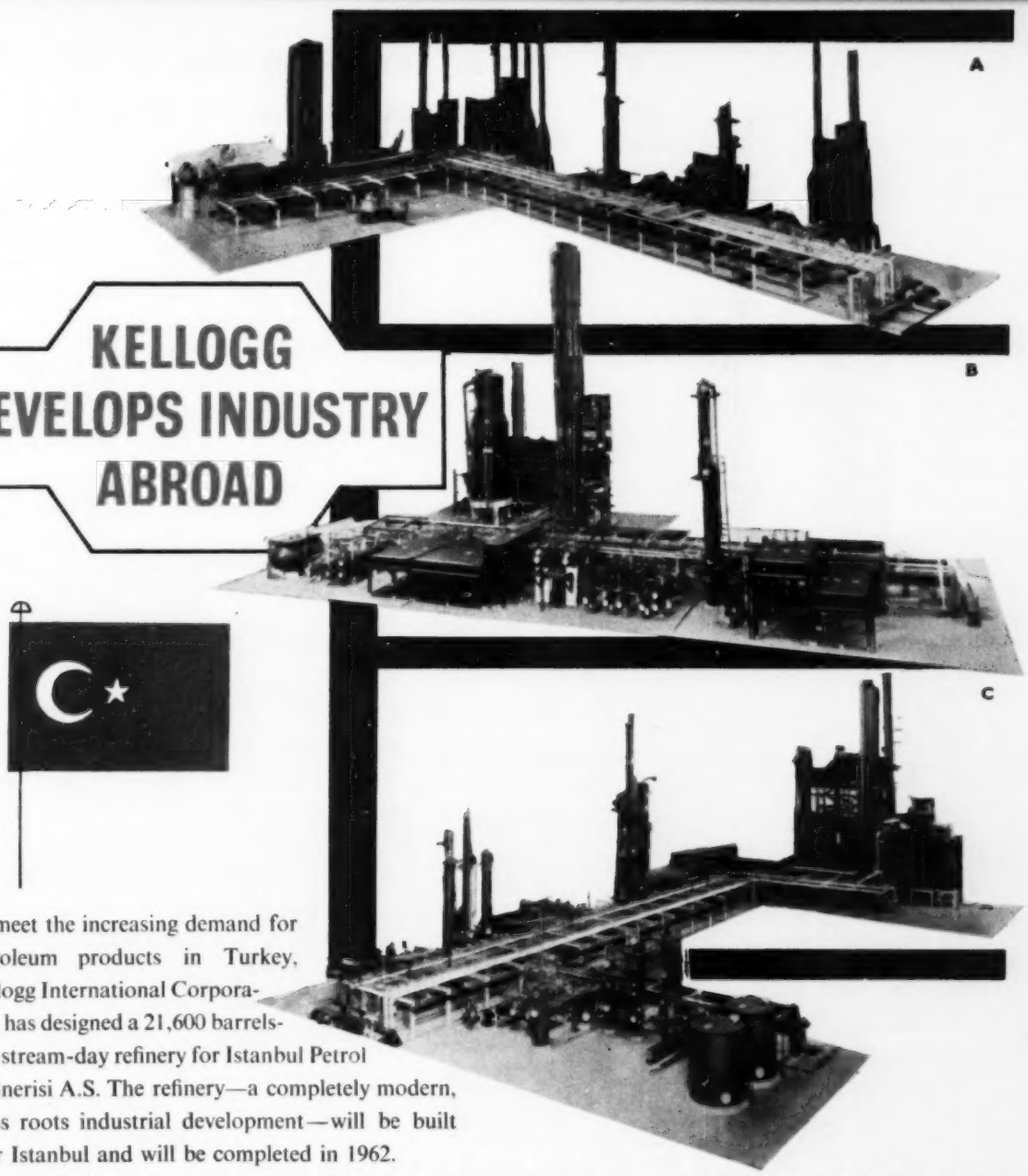

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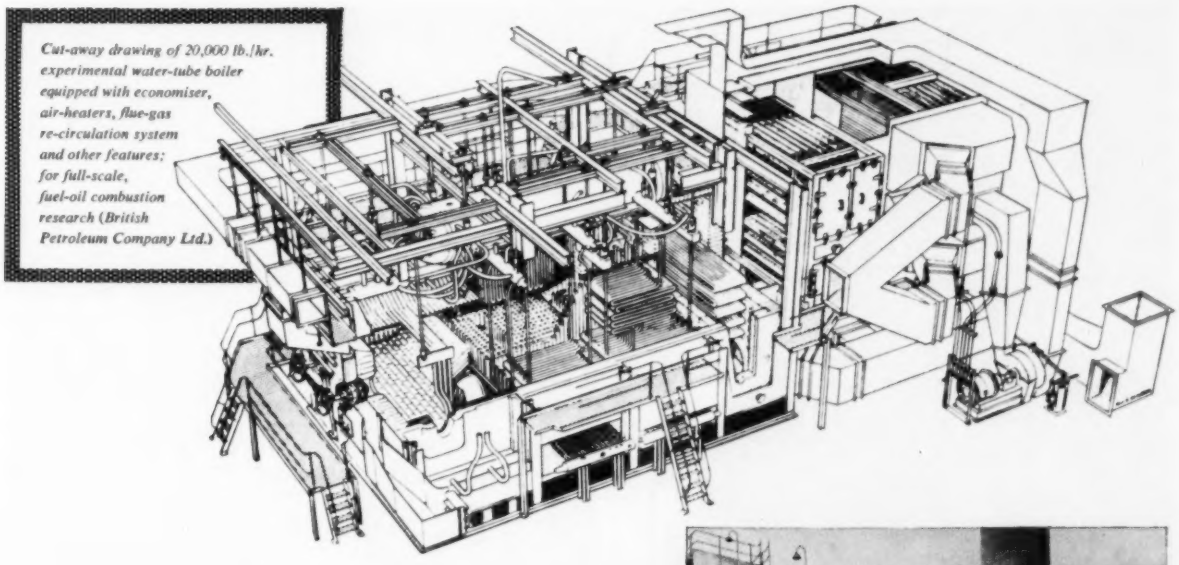

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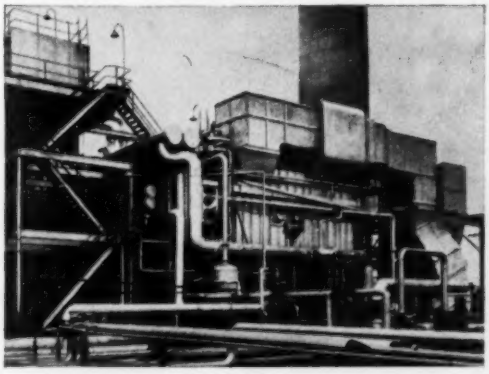

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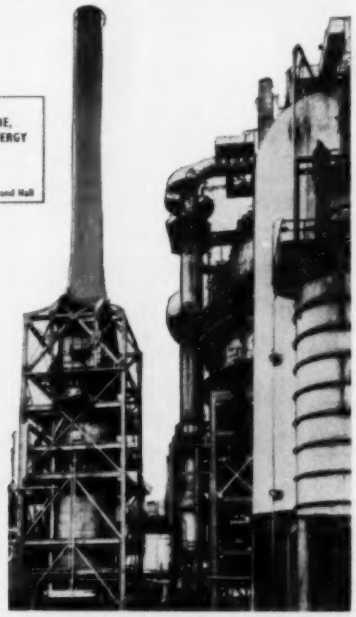

300,000 lb./hr. CO boiler, operating on "waste" gases from a catalytic cracker; (Esso refinery Fawley).

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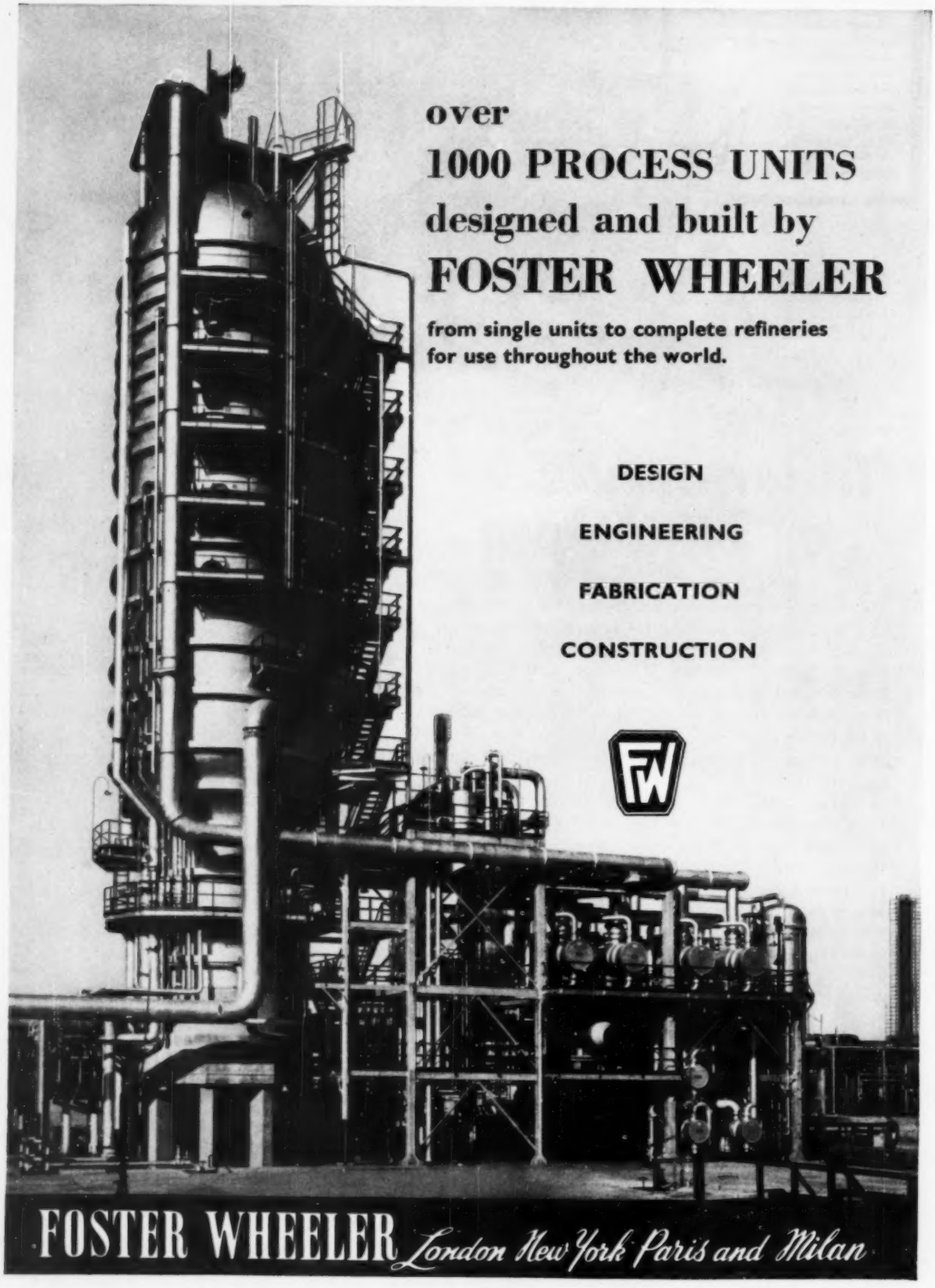
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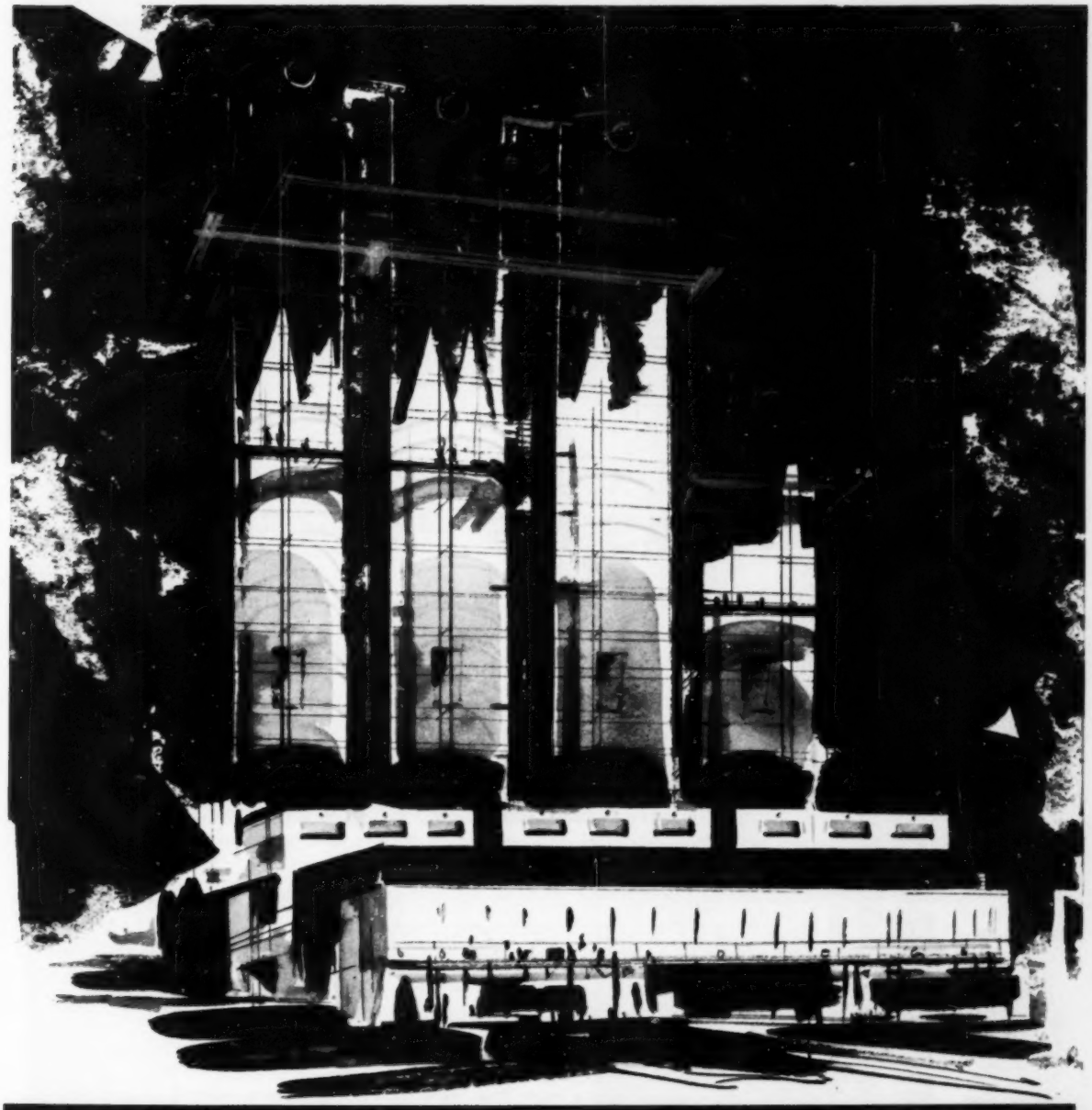

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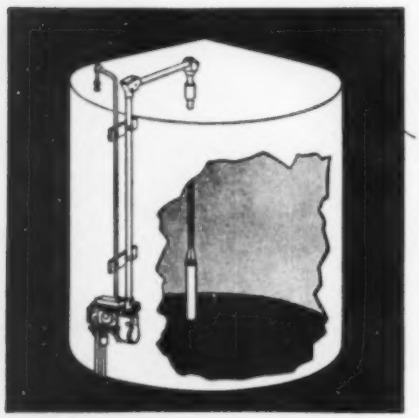
THE GILBARCO FIRTH CLEVELAND TANK GAUGE is a highly sensitive electronic device for local and remote indication of the level of liquids—or liquid interfaces—in deep tanks of all shapes and sizes. It gives continuous readings of level for liquids of any specific gravity and it is accurate within a few thousandths of an inch—this is particularly important in tanks with a large free surface area.

The instrument is suitable for use in hazardous areas and in extreme temperatures and it will operate data reduction or logging equipment. One remote indicator can be arranged to show the contents of up to 30 tanks in turn.

Routine maintenance can be carried out without taking the tank out of service.

These gauges are available to American Class 1 Group D Division 1 classification. We are shortly producing them to meet Buxton flameproof requirements.

The range of Firth Cleveland Instruments includes Electrical, Mechanical and Hydrostatic Tank Gauges, Pressure Operated Switches, and Pressure Relief Valves. We shall be happy to send you full particulars.



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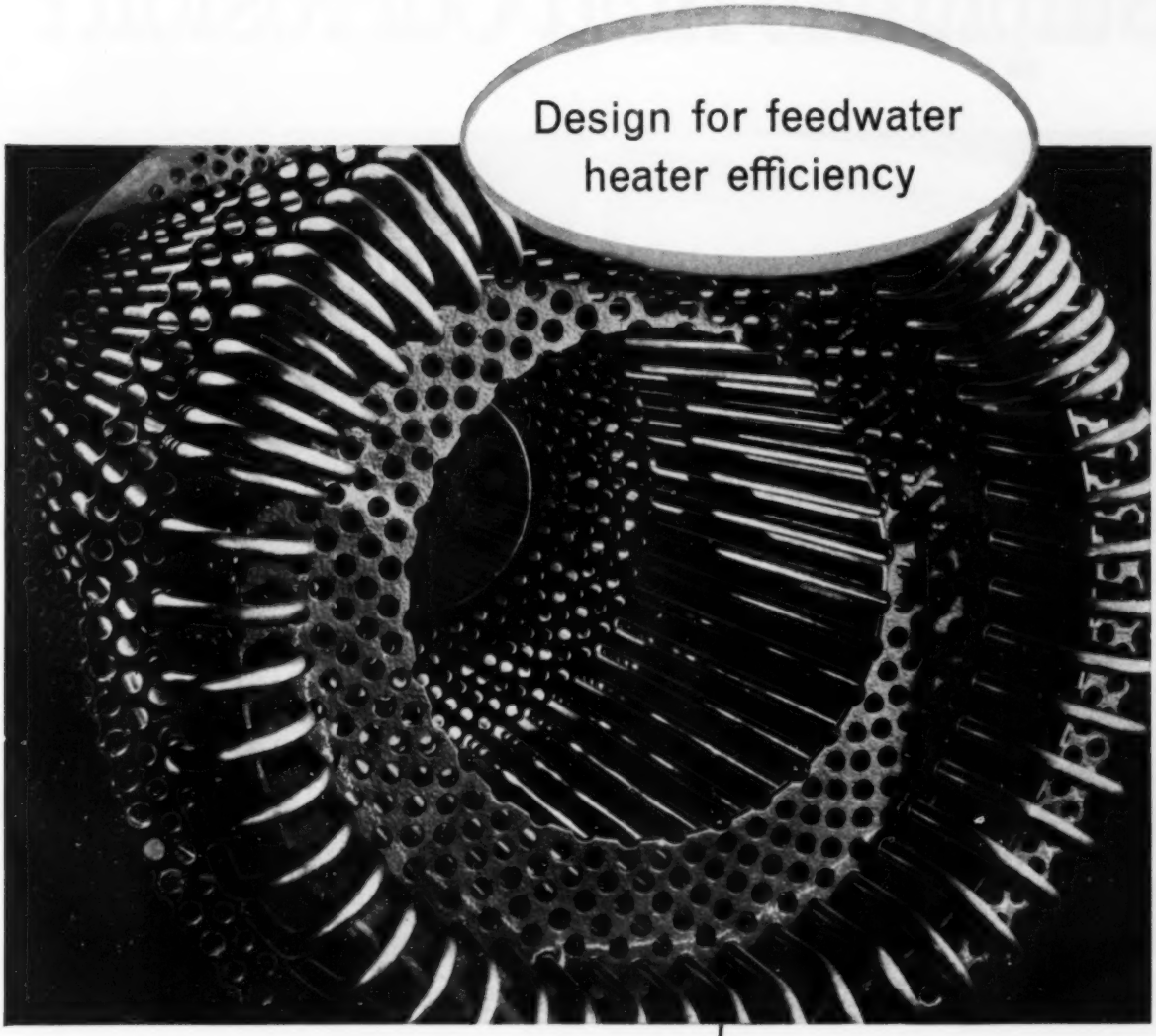

This partially assembled feedwater heater nest is designed to accept steam at 800°F and it incorporates 30,000 feet of solid drawn steel tube.

The AEI Turbine-Generator Division at Petershill Works, Glasgow, manufactures feedwater heaters and a wide variety of heat exchangers from the smallest cooler to the largest surface condenser. AEI experience and skill can solve your heat exchange problems.

For further information write to the AEI Turbine-Generator Division, Trafford Park, Manchester 17, or to your local AEI office.

Products include:
FEED HEATERS · DEAERATORS
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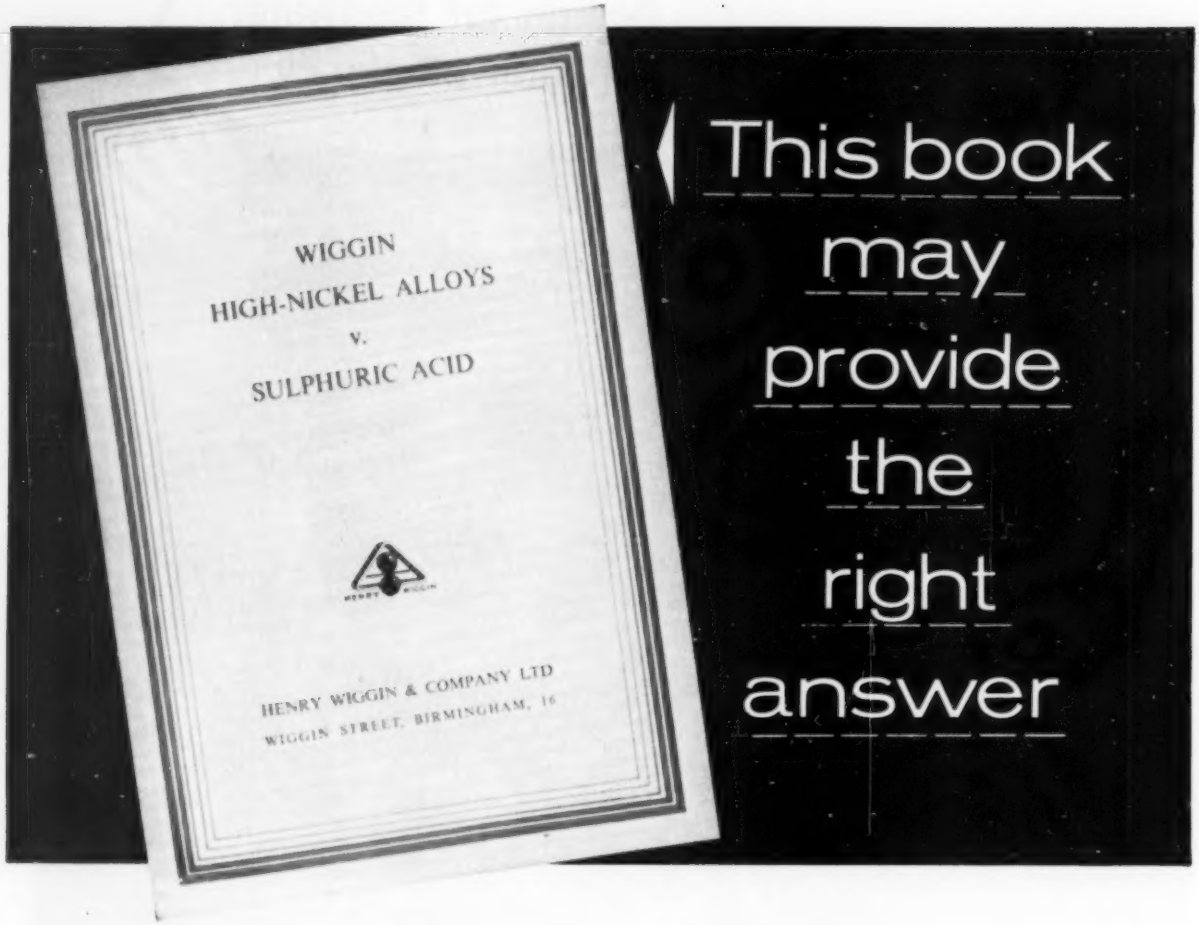
Sulphuric Acid Corrosion?



IF YOU ARE FACED WITH SULPHURIC ACID CORROSION PROBLEMS

you need this new handbook. It gives advice on the choice of suitable high-nickel alloys for many applications, backed by the results of hundreds of plant and laboratory tests.

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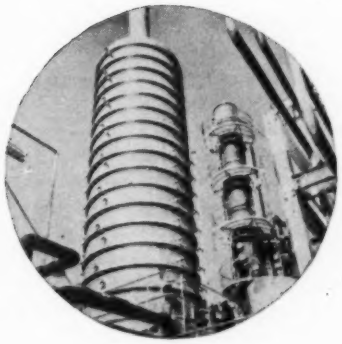
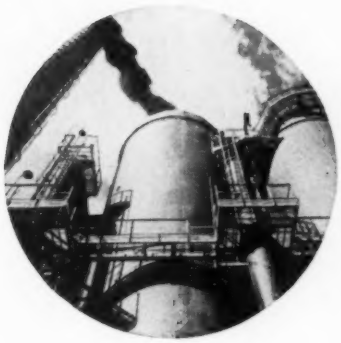


SYSTEM ENGINEERING FOR THE PROCESS INDUSTRIES



Production has begun of a new form of on-line process control computer and this has opened up a field of engineering of great interest and vast possibilities. Opportunities now exist for Engineers to join the team which is developing and applying computing equipment in process control systems. The following vacancies must be filled urgently.

CHEMICAL OR PETROLEUM ENGINEER

An Engineer is required with wide experience in the chemical and petroleum industry who now wishes to advance his knowledge, experience and professional standing by working in the forefront of a new field of technology.

PROCESS INSTRUMENT ENGINEER

This Engineer will be required to use his expert knowledge of present day process control instrumentation to assist in the integration of new computing systems with existing industrial processes.

MATHEMATICIAN

An experienced Mathematician is required who will show considerable initiative and originality in analysing problems in control and in devising schemes for optimisation. His experience should include system analysis and operational research.

Replies in confidence should be addressed to:—

The Personnel Manager, Ref. 134
The de Havilland Aircraft Company Limited
Hatfield, Herts.

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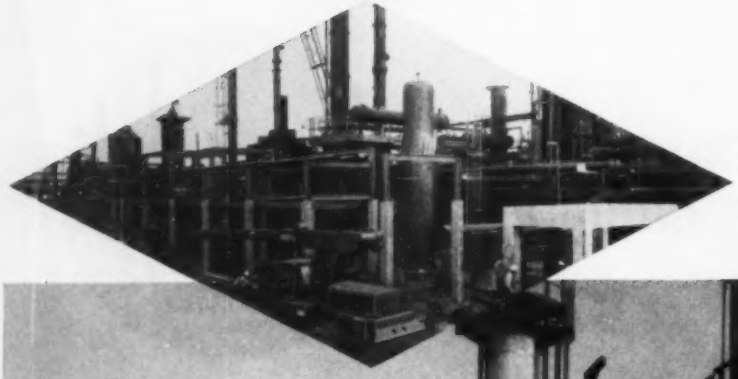
ON-SITE WITH PROCON

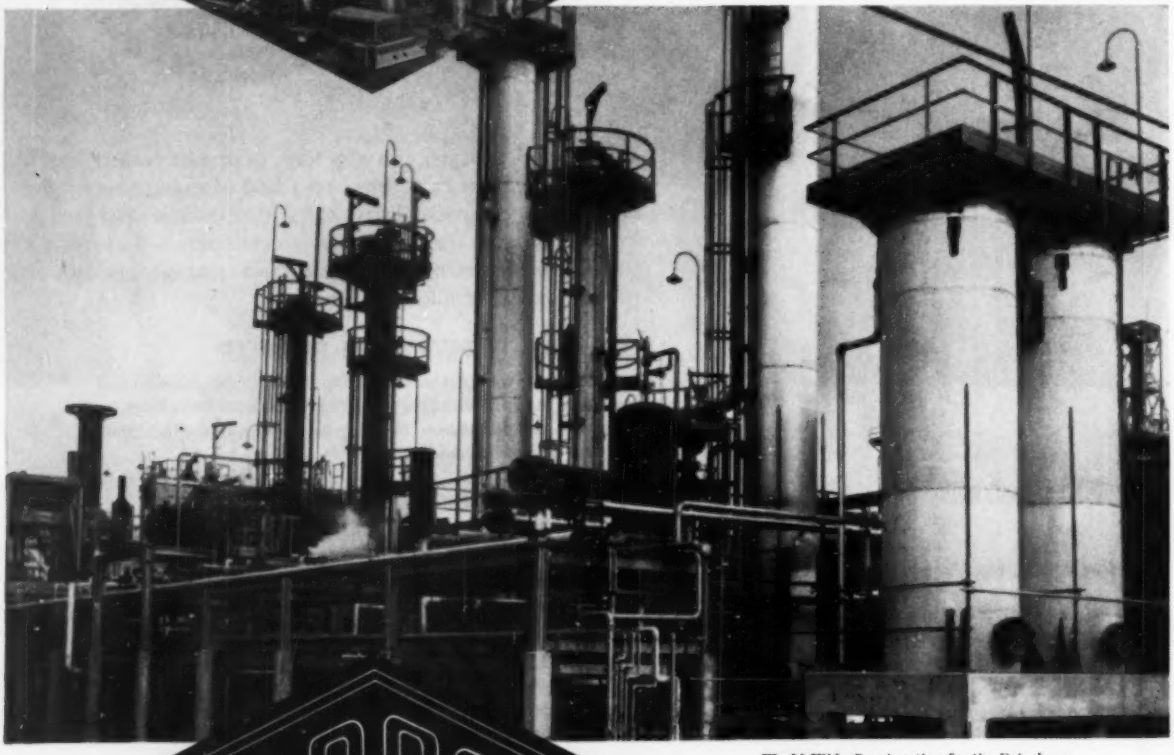


Procon-built Hydeal unit on-stream in 95 days!

Building a complicated process unit from the ground up requires the skillful coordination of a multitude of design, engineering, procurement and construction details.

It takes plenty of work, but most of all it takes time. Procon needed just 95 days from groundbreaking to on-stream acceptance of this Hydeal™ unit built for Signal Oil & Gas Company, in Houston, Texas. This highly efficient Hydeal unit produces 1,000 barrels-per-day of high quality benzene from a toluene charge. Signal markets the benzene direct to users in the Southwest.

New plant construction, expansion or modernization, whatever the requirement, you can trust the entire job . . . safely to PROCON.



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